BIOL 4640 Mol Micro
Lecture 20 10/12/26g
Cell Structures Part 6

- Assignment 14: In class Activity, Due on 10/12
- Assignment 15: Lecture 19 In class Activity Due on 10/14
- Assignment 16 Microbe Project coming
- Pick up Graded Exam 1 Short answer
- Lab students need to streak plates after class

BIOL 4640
Exam 1, 2026

- 103 pts possible (1 extra question for extra credit)
- (MC correct x 3) + short answer
- Ave 80.1 High 103

Scale	points	# students
A	89-102	15
B	79-88.5	1
C	69-78.5	7
	< 69	6

Unit 3. Features and Structures of Microbial Cells - D

A. Size and Shape of bacteria
B. Specialized External Structures of bacteria
C. Cell envelope of bacteria
D. Internal structures of bacteria
E. Cell Division in Bacteria
F. Viruses – Chapter 6
G. Unusual bacteria and viruses

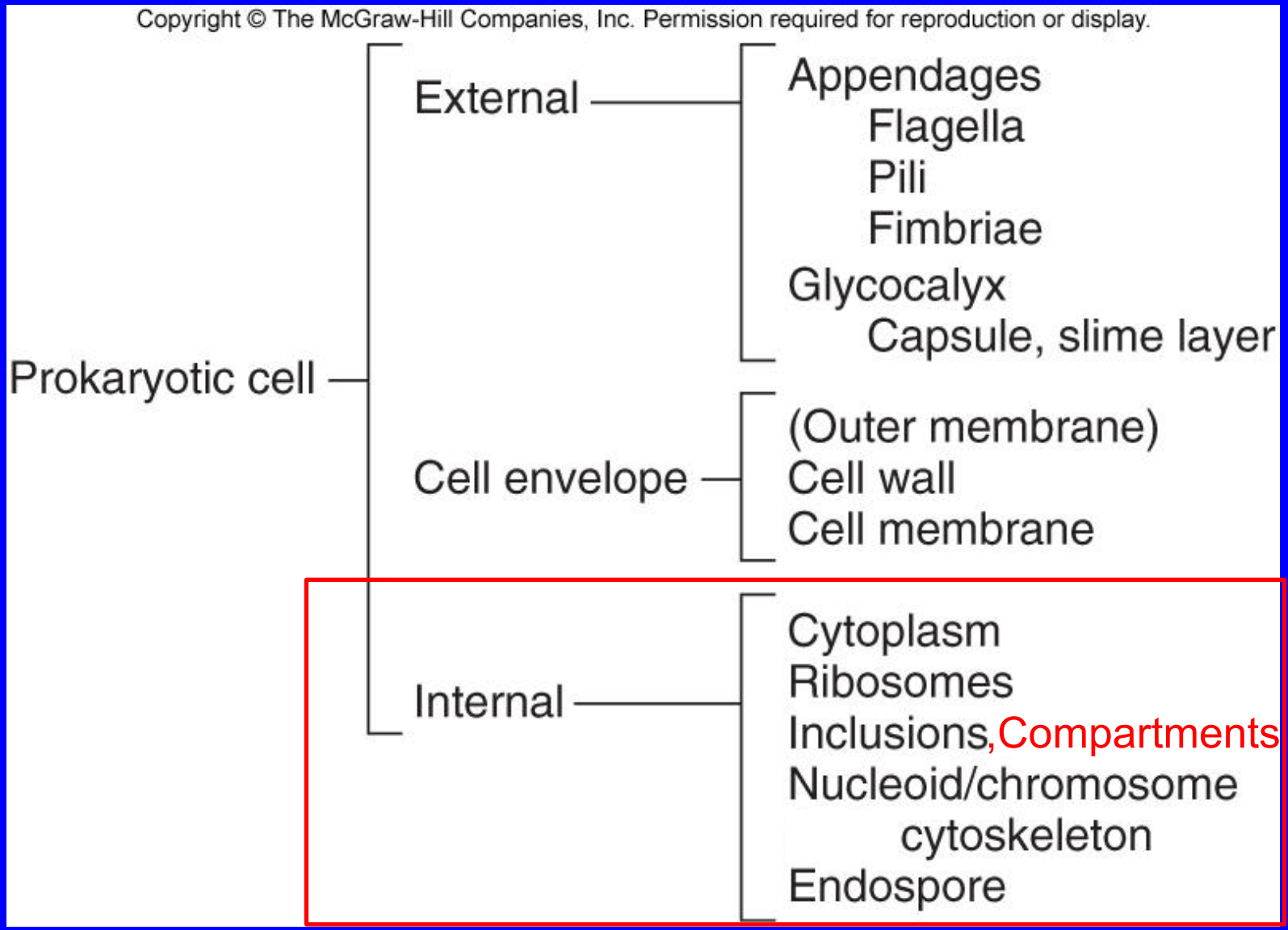
Mostly Chapter 3 in book

D. Internal Structures outline

1. Cytoplasm
2. Ribosomes
3. Cytoskeleton
4. Nucleoid
5. Compartments
6. Inclusions and Granules
7. Endospores

3. Internal Structures revised

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Bacterial Internal Structures

1. Cytoplasm – everything inside cell membrane

   Contains

   – Cytosol – liquid portion of cytoplasm
   – A variety of minerals, salts and proteins, sugars, etc. dissolved in water
   – Nucleoid – tightly coiled DNA
   – Inclusions - Aggregates of proteins and other material - most
   – Membrane-bound compartments – a few have

1. Cytoplasm - 1

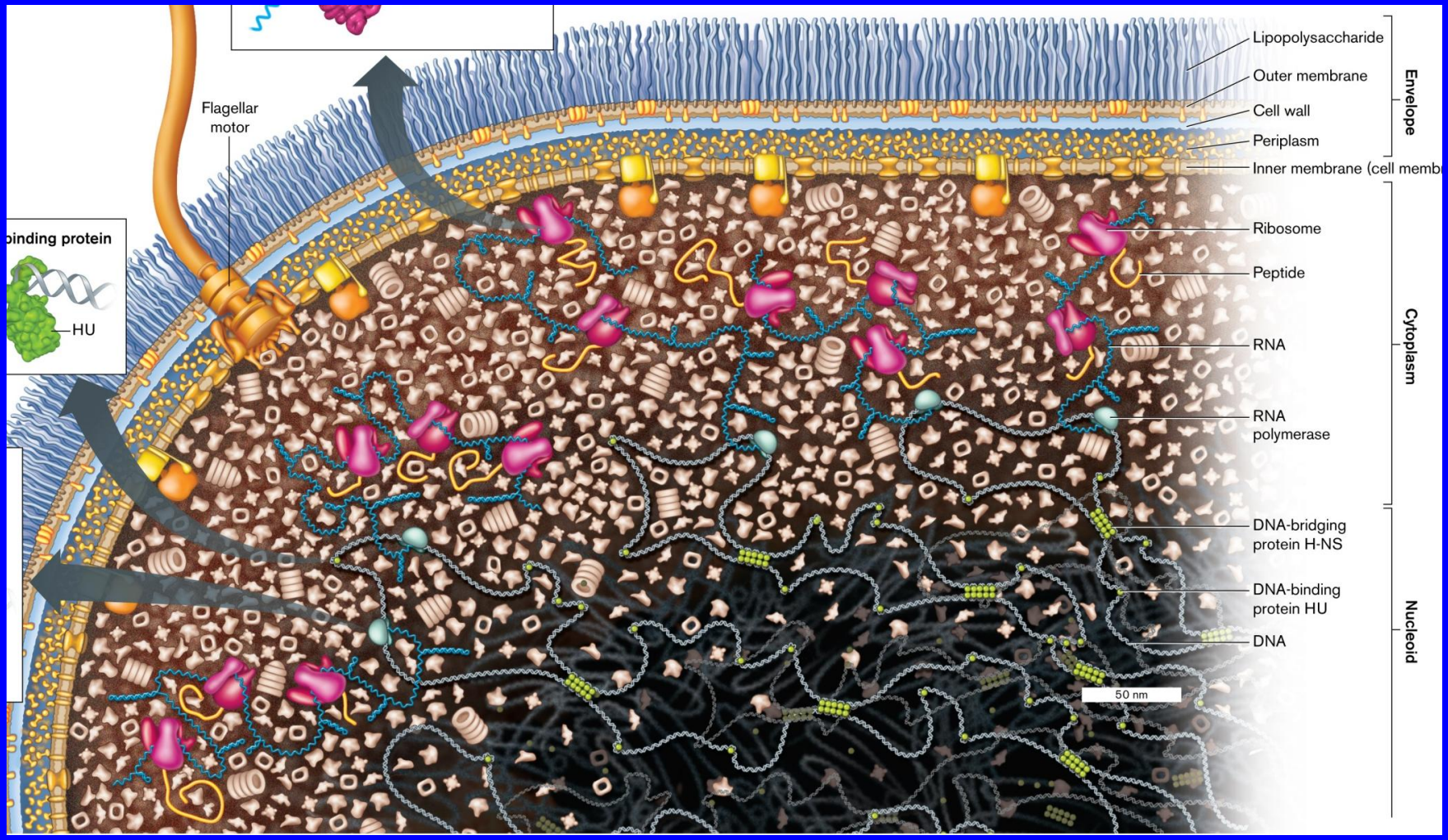


Figure 3.1c 6th edition S F Micro

1. Cytoplasm - 2

- Here they tried to estimate the number of each component per cell

TABLE 3.1 Molecules of a Bacterial Cell, *Escherichia coli*, during Balanced Exponential Growth[a]

Component	Percentage of total weight[b]	Approximate number of molecules/cell	Number of different kinds
Water	70	20,000,000,000	1
Proteins	16	2,400,000	4,000[c]
RNA:			
rRNA, tRNA, and other small RNA (sRNA) molecules	6	250,000	200
mRNA	0.7	4,000	2,000[c]
Lipids:			
Phospholipids (membrane)	3	25,000,000	50
Lipopolysaccharides (outer membrane)	1	1,400,000	1
DNA	1	2[d]	1
Metabolites and biosynthetic precursors	1.3	50,000,000	1,000
Peptidoglycan (murein sacculus)	0.8	1	1
Inorganic ions	0.1	250,000,000	20
Polyamines (mainly putrescine and spermidine)	0.1	6,700,000	2

[a]Values shown are for a hypothetical "average" cell cultured with aeration in glucose medium with minimal salts at 37°C.

[b]The total weight of the cell (including water) is about 10^{-12} gram (g), or 1 picogram (pg).

[c]The number of different kinds is difficult to estimate for proteins and mRNA because some genes are transcribed at extremely low levels and because proteins and RNA include kinds that are rapidly degraded.

[d]In rapidly growing cells, cell fission typically lags approximately one generation behind DNA replication; hence, two identical DNA copies per cell.

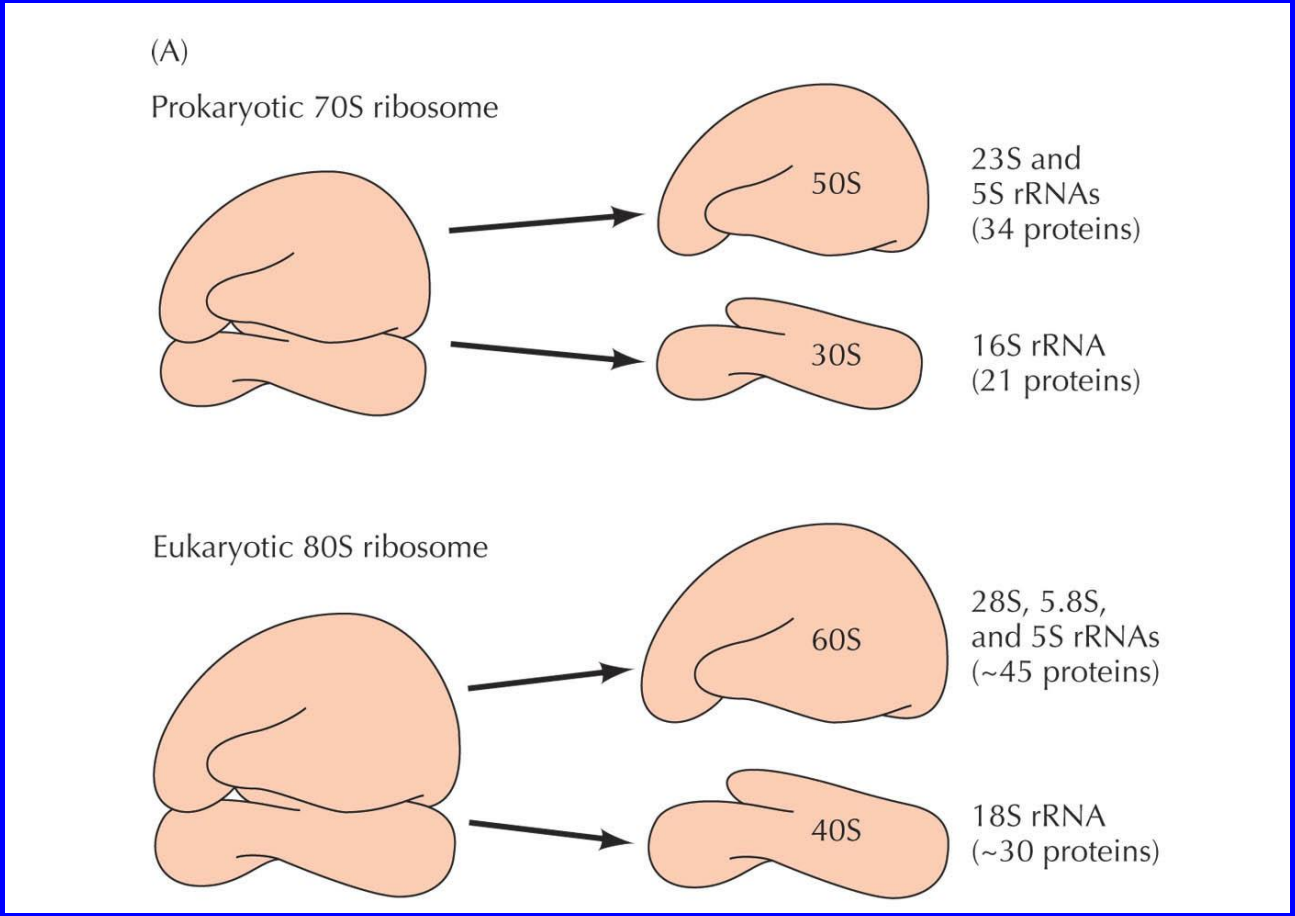
Source: Modified from F. Neidhardt and H. E. Umbarger. 1996. Chemical composition of *Escherichia coli*, p. 14. In F. C. Neidhardt (ed.), *Escherichia coli and Salmonella: Cellular and Molecular Biology*, 2nd ed. ASM Press, Washington, DC.

1. Cytoplasm - 3

- Crowded with macromolecules, particularly ribosomes (~15,000 per cell)
  - 60-70% of wet weight of cytoplasm is water
  - 20% of weight protein
  - 7-20% RNA (rRNAs – 65% of ribosomes)
  - 3% lipid
  - 1-2 % DNA
- Viscous –
  - Rate of diffusion is reduced 10 fold

2. Ribosomes

- Differs in size and components from eukaryotic
- Selectively inhibited by some antibiotics



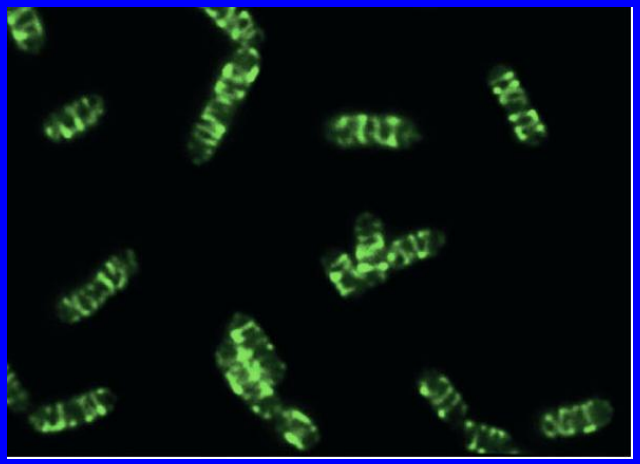
Inhibitors of Translation

Inhibitor	Action
Chloramphenicol	Inhibits peptidyl transferase on the prokaryotic large subunit
Cycloheximide	Inhibits peptidyl transferase on the eukaryotic large subunit
Erythromycin	Inhibits translocation by the prokaryotic large subunit
Fusidic acid	Inhibits elongation in prokaryotes by binding to EF-G · GDP in a way that prevents its dissociation from the large subunit
Paromomycin	Increases the ribosomal error rate
Puromycin	An aminoacyl–tRNA analog that causes premature chain termination in prokaryotes and eukaryotes
Streptomycin	Causes mRNA misreading and inhibits chain initiation in prokaryotes
Tetracycline	Inhibits the binding of aminoacyl–tRNAs to the prokaryotic small subunit
Diphtheria toxin	Catalytically inactivates eEF2 by ADP-ribosylation
Ricin/abrin/ -sarcin	**Ricin** and **abrin** are poisonous plant glycosidases that catalytically inactivate the eukaryotic large subunit by hydrolytically depurinating a specific highly conserved A residue of the 28S RNA, which is located on the so-called **sarcin–ricin loop** that forms a critical part of the ribosomal factor-binding center; **α-sarcin** is a fungal protein that cleaves a specific phosphodiester bond in the sarcin–ricin loop

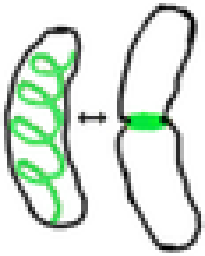
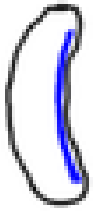
Some are antibiotic drugs used for bacterial infections
Some are toxins produced by organisms
Some are used for research purposes.

3. Cytoskeleton

- Have found homologs of all three types of eukaryotic cytoskeletal proteins
- Play role in cell division, cell polarity, cell shape regulation, plasmid partition, and other functions.



Stained actin fibers

	Division	Polarity	Shape
Eukaryotes	Tubulin	Actin	Intermediate filaments
Prokaryotes	FtsZ	MreB	CreS
Caulobacter localization			

3. Cytoskeleton - 2

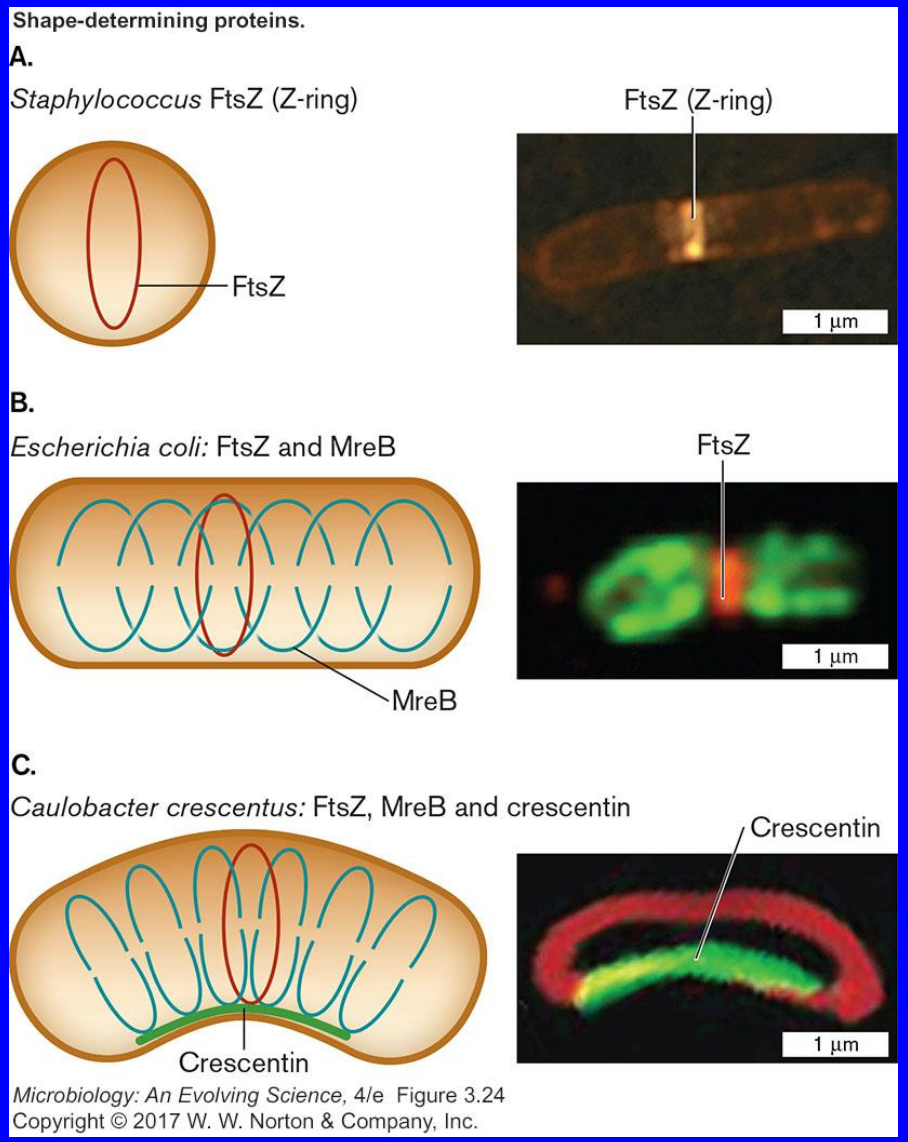
Figure 3.23 6th edition

Shows all 3 types of cytoskeletal filaments playing role in cell shape and cell division

FtsZ of Z ring: similar to tubulin

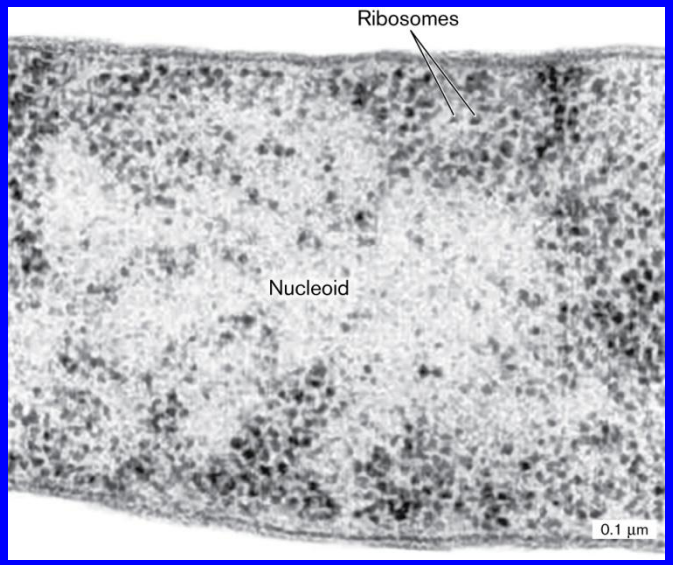
MreB: similar to actin

Crescentin: similar to intermediate



4. Nucleoid

a. Region in cytosol where chromosomal DNA is located
   - Lacks ribosomes (black dots or grains in EM image),



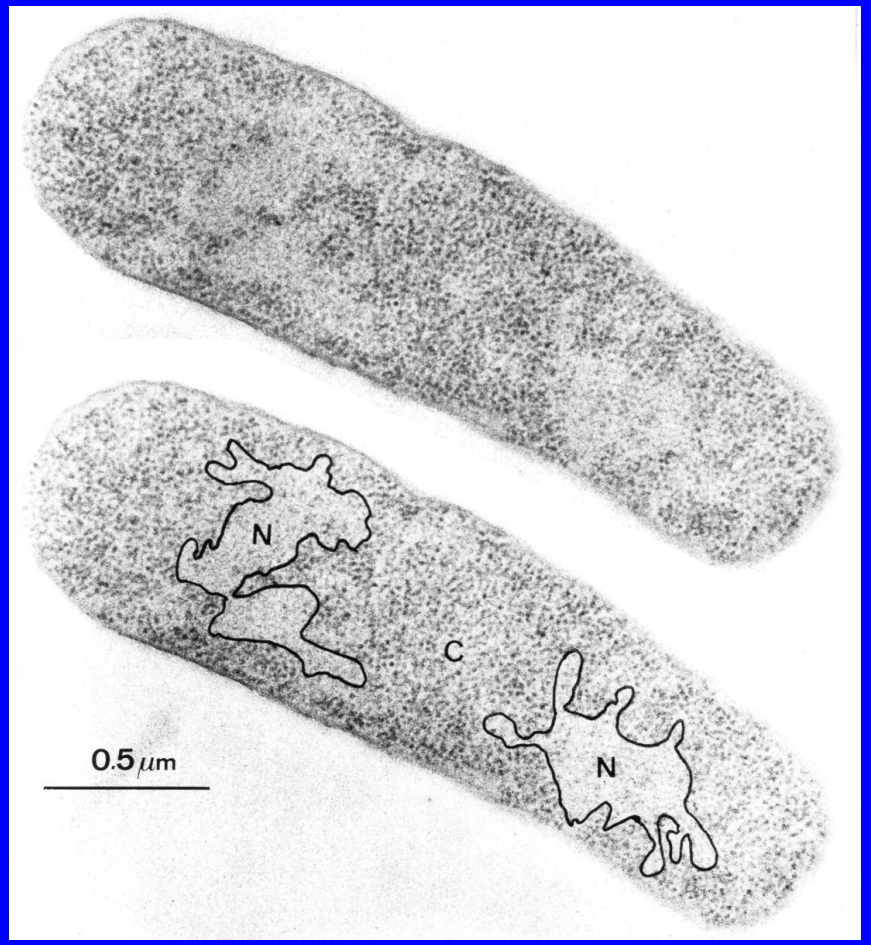


Figure 3.26a 4th edition

4. Nucleoid - 2

Image: colorized cryo-electron tomograph of *Bdellovibrio bacteriovorus*

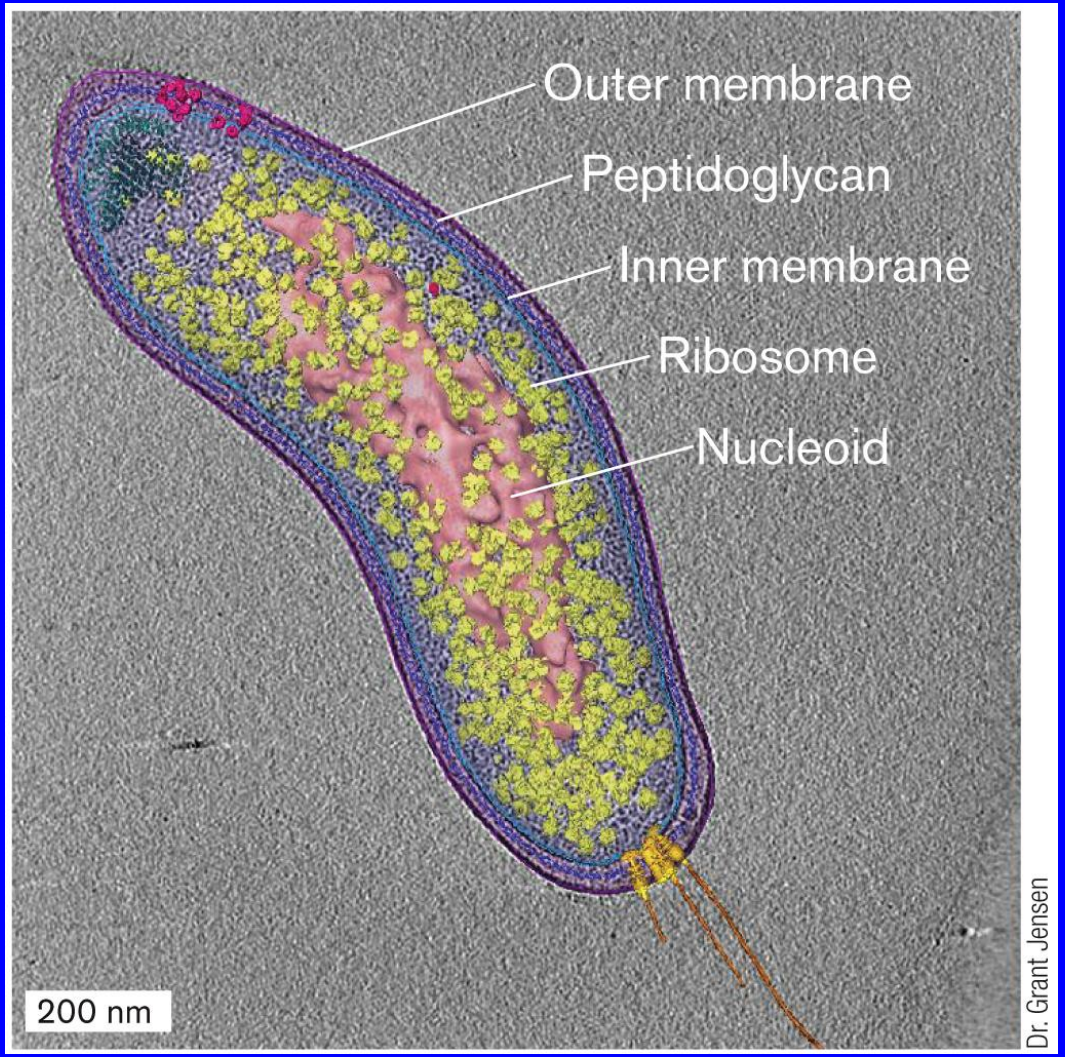


Figure from Chapter 3 6th edition

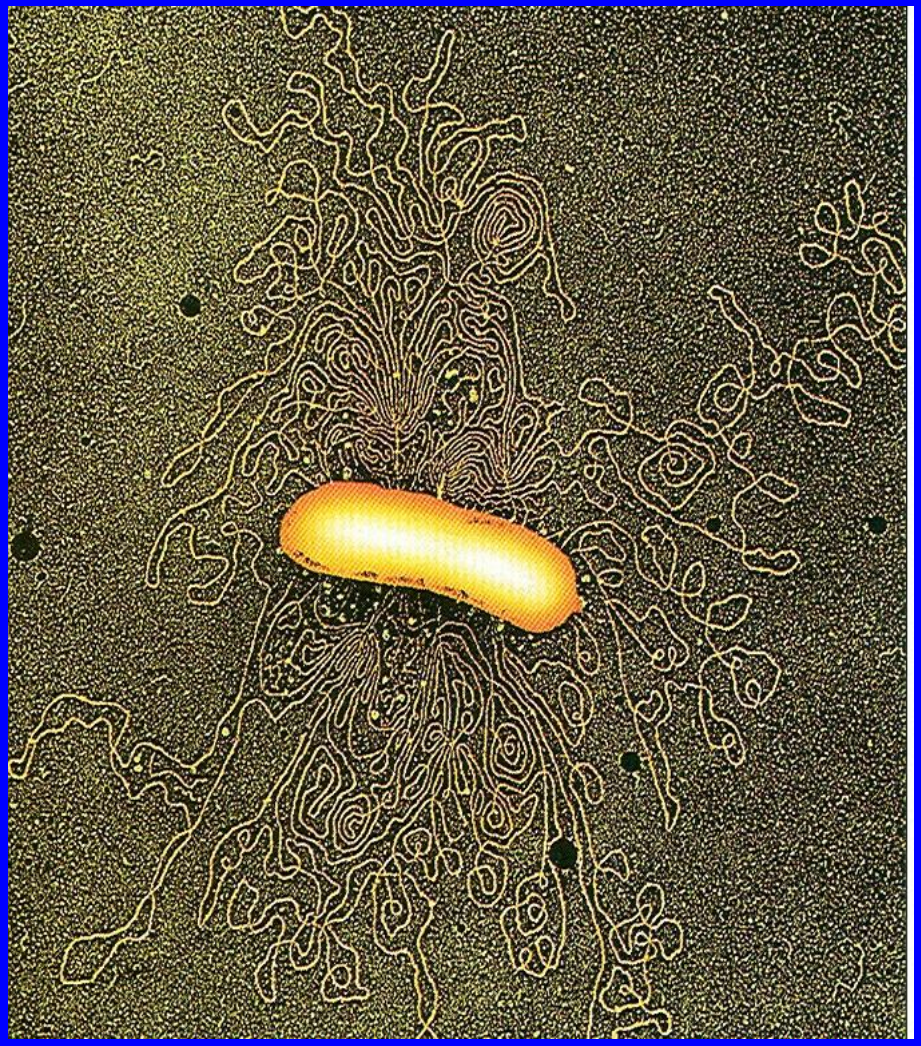
4. Nucleoid - 3

b. Bacterial DNA is packed and condensed
   - Mechanism of packing is not well understood
     – No histone proteins
   - Mediated in part by binding of several common DNA binding proteins (HU, IHF, H-NS, Fis) that bind DNA but with low sequence specificity
     - HU – is similar to a histone protein
   - Negatively supercoiled by topoisomerases
   - In loops

4. Nucleoid - 4

DNA becomes less condensed once cell is lysed and can makes the solution viscous

Figure shows uncondensed DNA released from one bacterial cell
See Figure 7.6 in 6th edition



4. Nucleoid - 5

c. DNA is organized into loops of about 50 kB and supercoiled

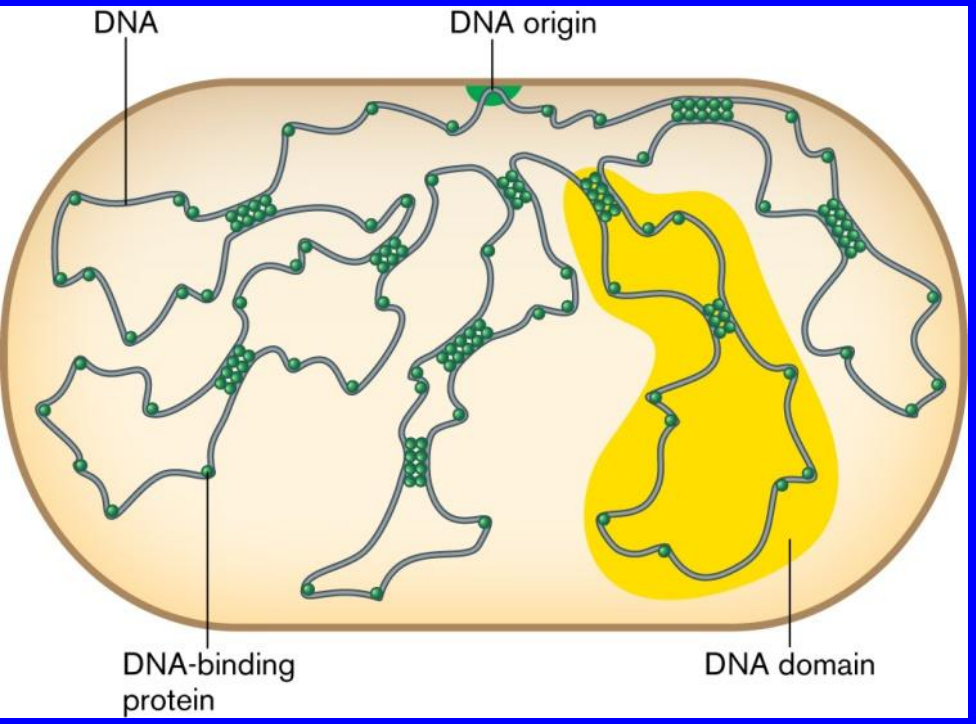
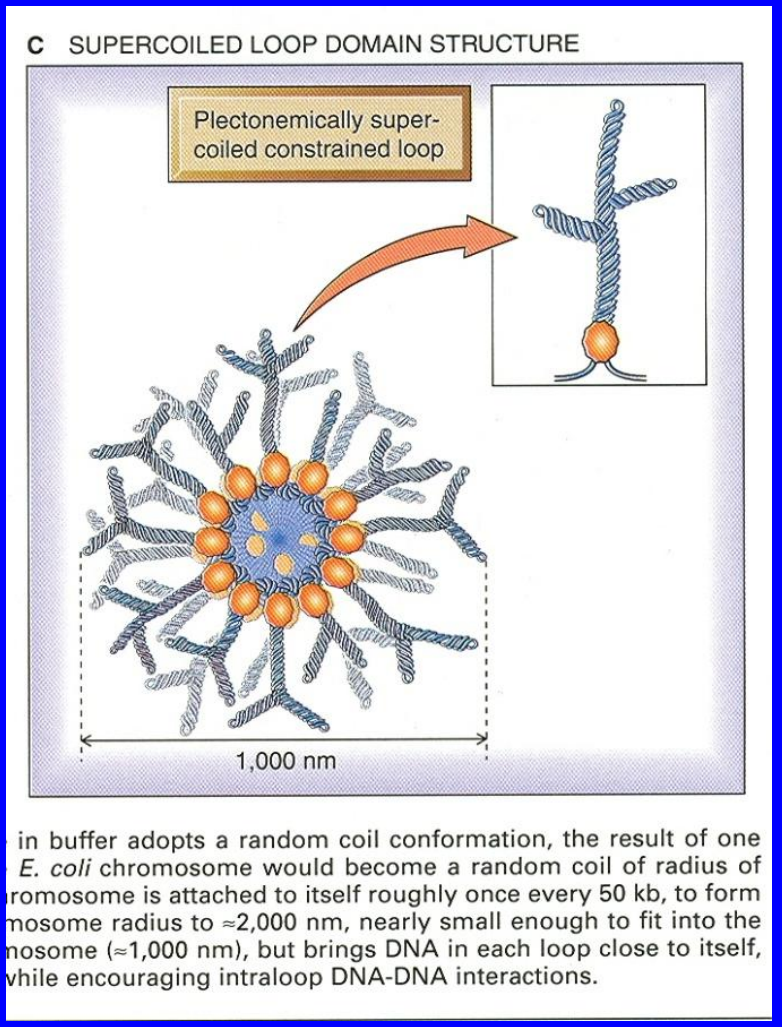


Figure 3.26b 4th edition



in buffer adopts a random coil conformation, the result of one *E. coli* chromosome would become a random coil of radius of romosome is attached to itself roughly once every 50 kb, to form mosome radius to ≈2,000 nm, nearly small enough to fit into the nosome (≈1,000 nm), but brings DNA in each loop close to itself, while encouraging intraloop DNA-DNA interactions.

4. Nucleoid - 6

d. DNA appears to be located inside a membrane compartment in one type of bacterium (Planctomycetes)

Figure: *Gemmata* bacterium– Chromosome inside two membranes

- Nuclear membrane – double membrane
- Inner cell membrane

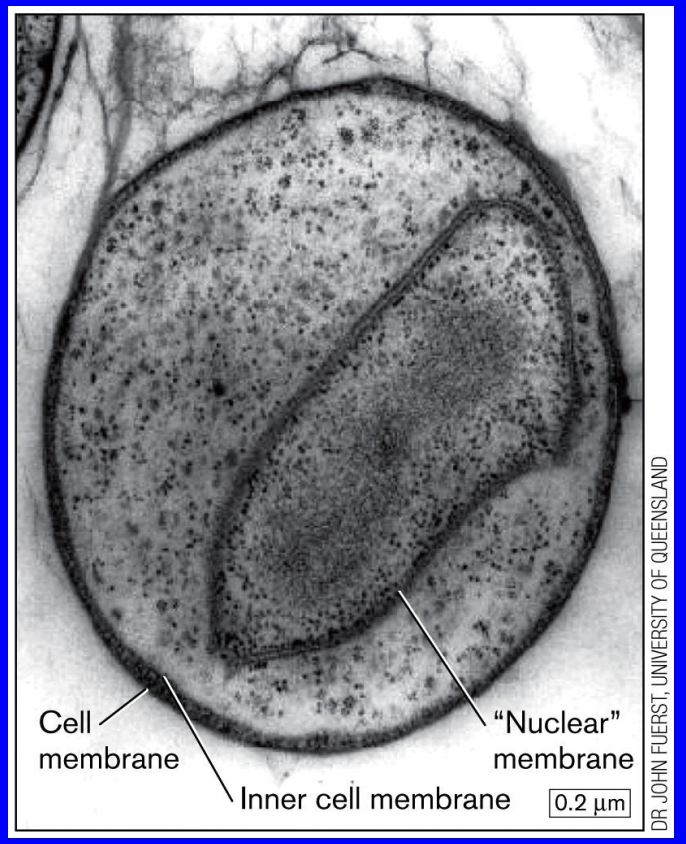


Figure 18.47A
6th edition

Bacterial Internal Structures - 2

5. Membrane Structures - Compartments
   - Structures (organelles) surrounded by a lipid membrane thus making a compartment
   - Observed in some bacteria (methanotrophs, nitrogen fixers, nitrifers, phototrophs)
   - Have specialized physiological role –
     - Carry out specific metabolic reactions in and across the membrane
     - Photosynthesis

Bacterial Internal Structures - 3

5. Membrane Structures – Compartments

Figure: Examples of phototrophic bacteria with intracellular membrane structures



Stolz Encyclopedia of Life Science 2007

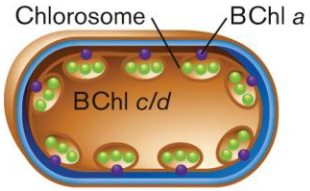
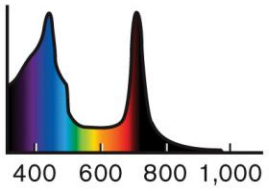
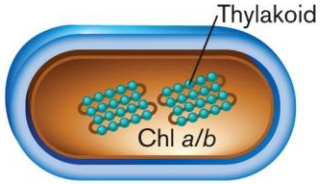
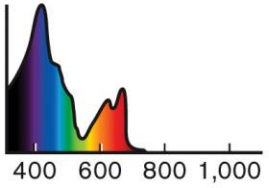
5. Intracellular Membrane Structures

Found in many types of phototrophic bacteria

a. Thylakoids in cyanobacteria

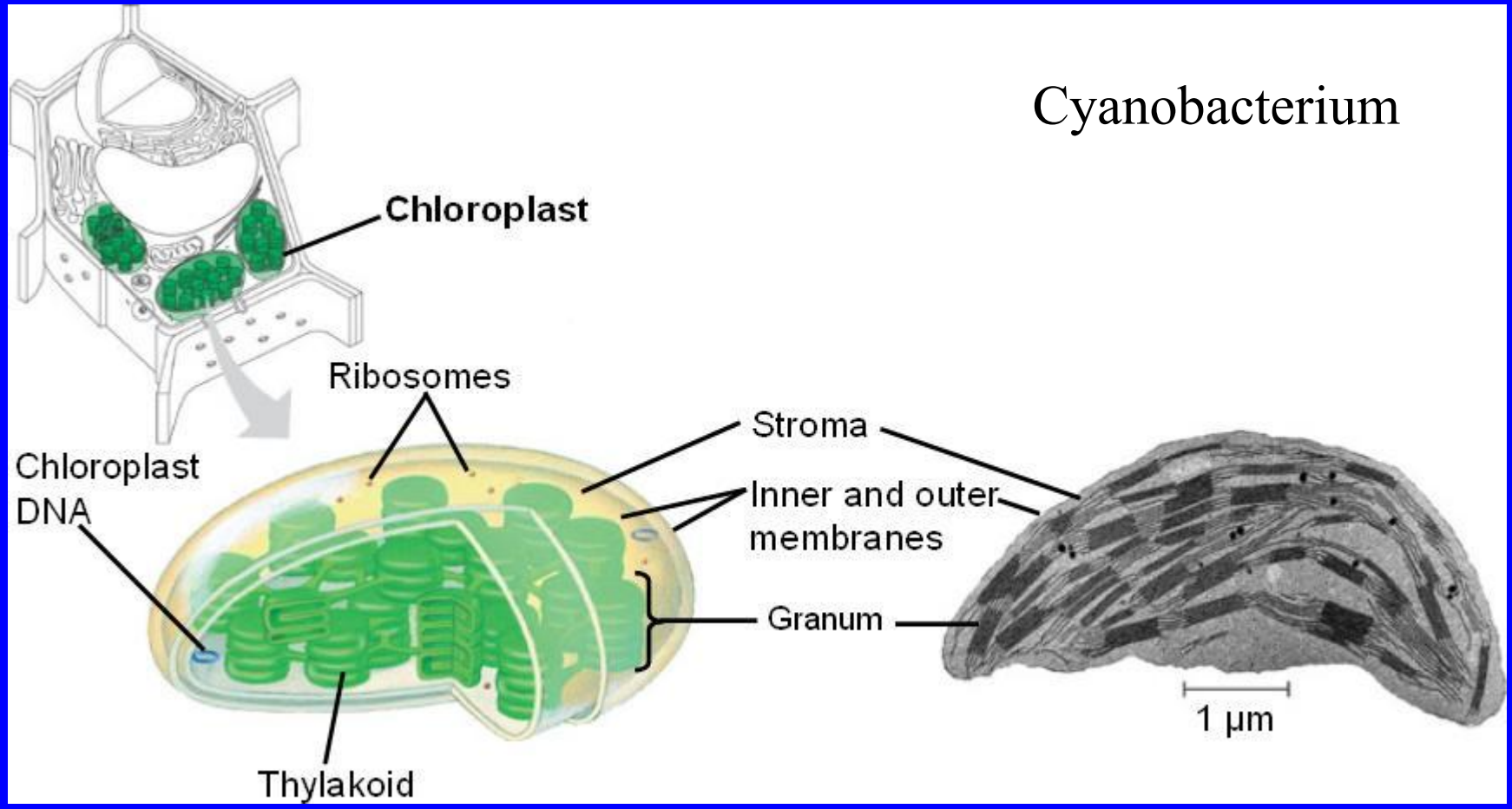
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TABLE 18.3 Phyla That Include Phototrophic Bacteria

Taxon	Energy generation	Cell structure and photopigments	Absorption spectrum (nm; whole cell)	Reaction center
Chloroflexi "Green nonsulfur" *Chloroflexus*	$+O_2$ Heterotrophy $-O_2$ Photoheterotrophy or use reduced sulfur			PS II
Cyanobacteria "Blue-greens" *Anabaena*	$+O_2$ Oxygenic phototrophy $-O_2$ Photolithoautotrophy on reduced sulfur			PS I and PS II

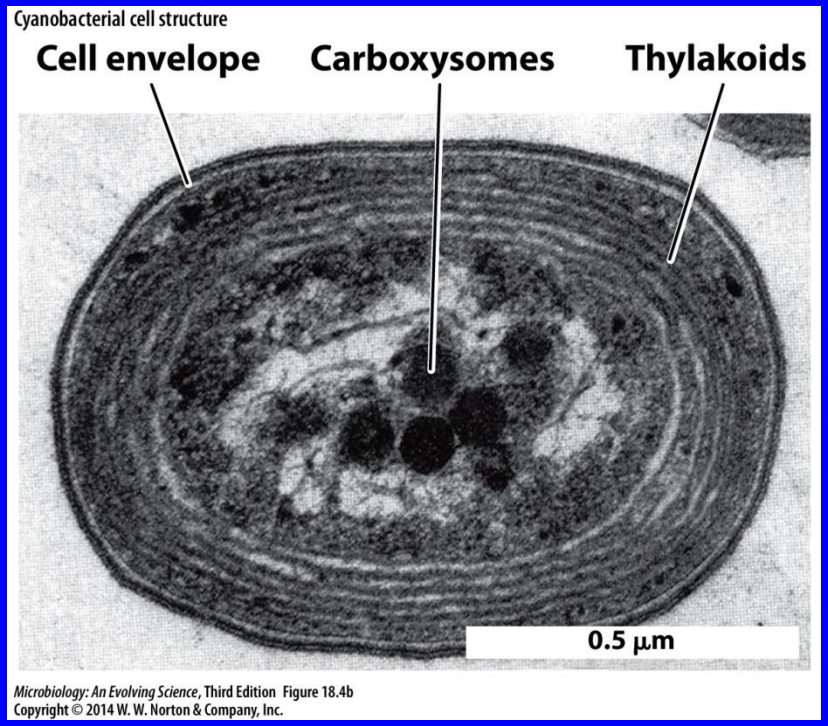
5. Intracellular Membrane Structures - 2

a. Thylakoids in cyanobacteria
   – Some similar to thylakoid in chloroplasts



5. Intracellular Membrane Structures - 3

a. Thylakoids in cyanobacteria
   - Site of light harvesting reactions
   - Membranes have full lipid bilayers



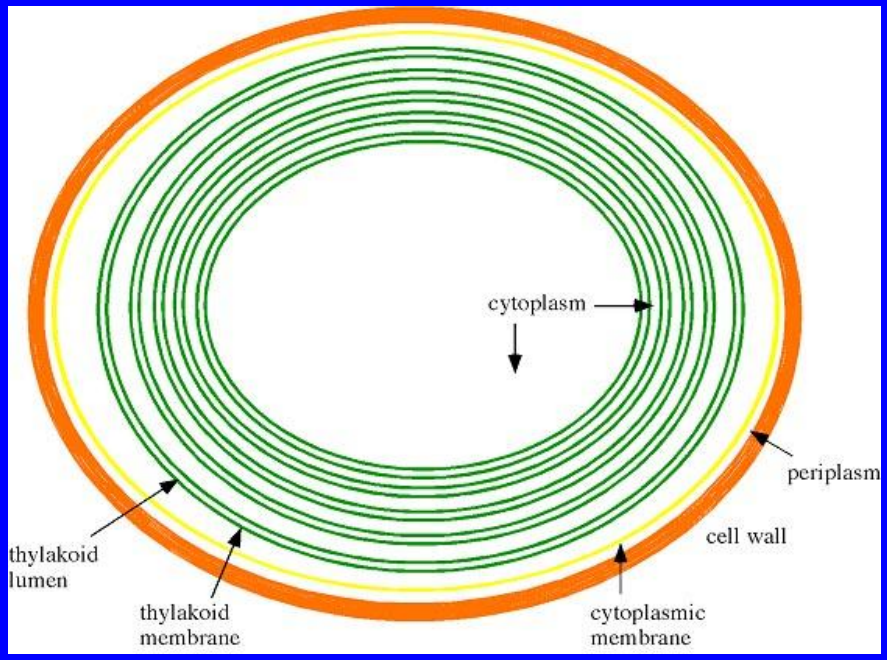


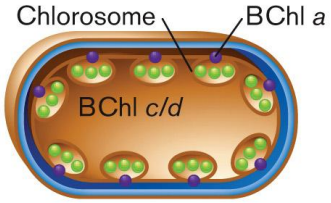
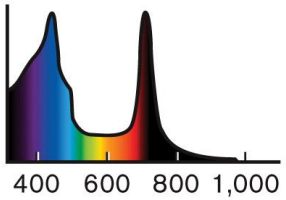
Figure 18.5b 4th edition Prochlorococcus – marine phototrophic bacteria

5. Intracellular Membrane Structures - 4

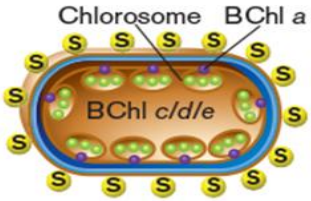
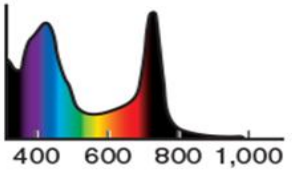
b. Chlorosomes in Green sulfur and nonsulfur phototrophic bacteria

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TABLE 18.3 Phyla That Include Phototrophic Bacteria

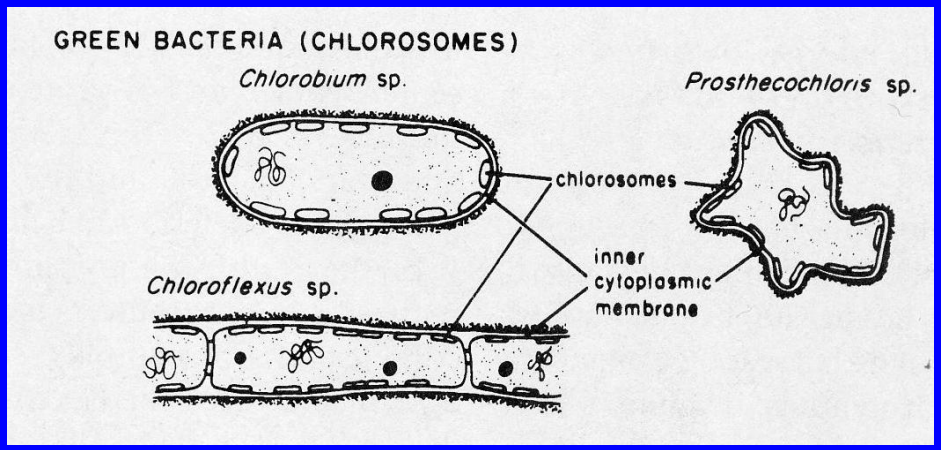
Taxon	Energy generation	Cell structure and photopigments	Absorption spectrum (nm; whole cell)	Reaction center
Chloroflexi "Green nonsulfur" *Chloroflexus*	$+O_2$ Heterotrophy $-O_2$ Photoheterotrophy or use reduced sulfur			PS II

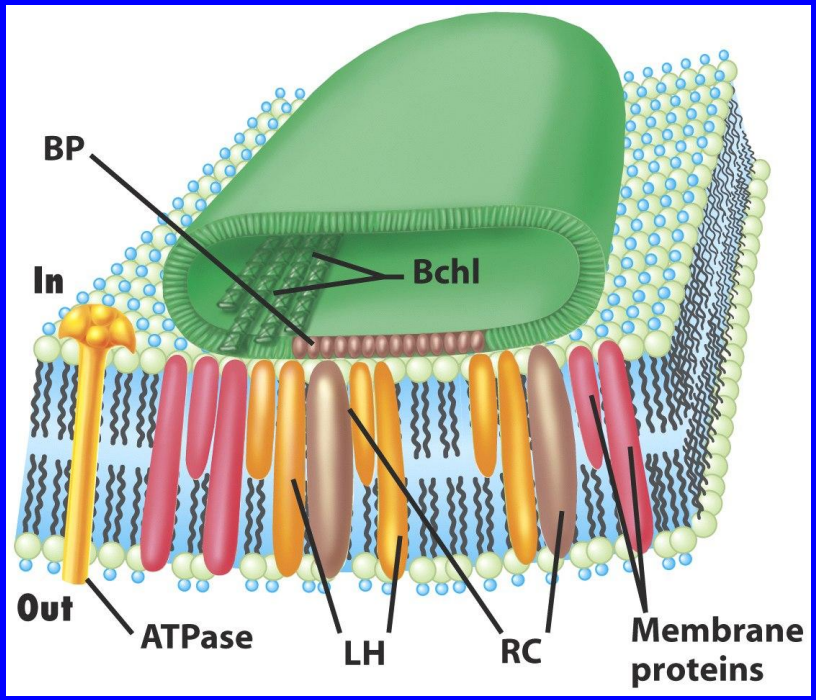
From 4th edition

Chlorobi "Green sulfur" *Chlorobium*	$-O_2$ only Photolithoautotrophy on reduced sulfur			PS I

5. Intracellular Membrane Structures - 5

b. Chlorosomes of Green bacteria
   - Single phospholipid monolayer linked to cell membrane
   - Contains light harvesting pigments



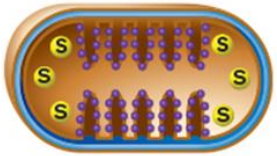
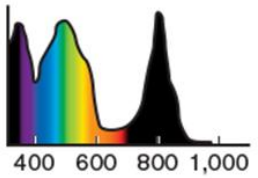
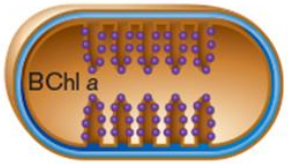
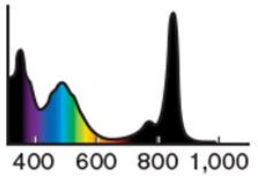
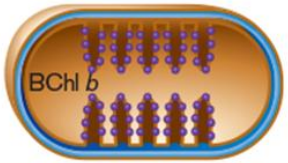
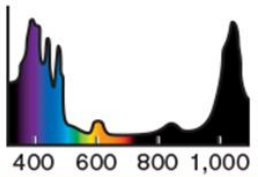


5. Intracellular Membrane Structures - 6

c. Invaginations found in purple sulfur and nonsulfur phototrophic bacteria – contiguous with cell membrane but site of photosynthetic reactions

From 4th edition

TABLE 18.2 Phototrophic Bacteria

Taxon	Energy generation	Cell structure and photopigments	Absorption spectrum (whole cell)	Reaction center
"Purple sulfur" (Gamma class) *Chromatium*	$+O_2$ $-O_2$ Photolithoautotrophy on reduced sulfur	BChl *a*/*b* 		PS II
Proteobacteria "Purple nonsulfur" (Alpha and Beta classes) BChl *a* *Rhodospirillum*	$+O_2$ Heterotrophy			PS II
BChl *b* *Blastochloris*	$-O_2$ Photoheterotrophy			

Microbiology: An Evolving Science, 4/e Table 18.2 part 2

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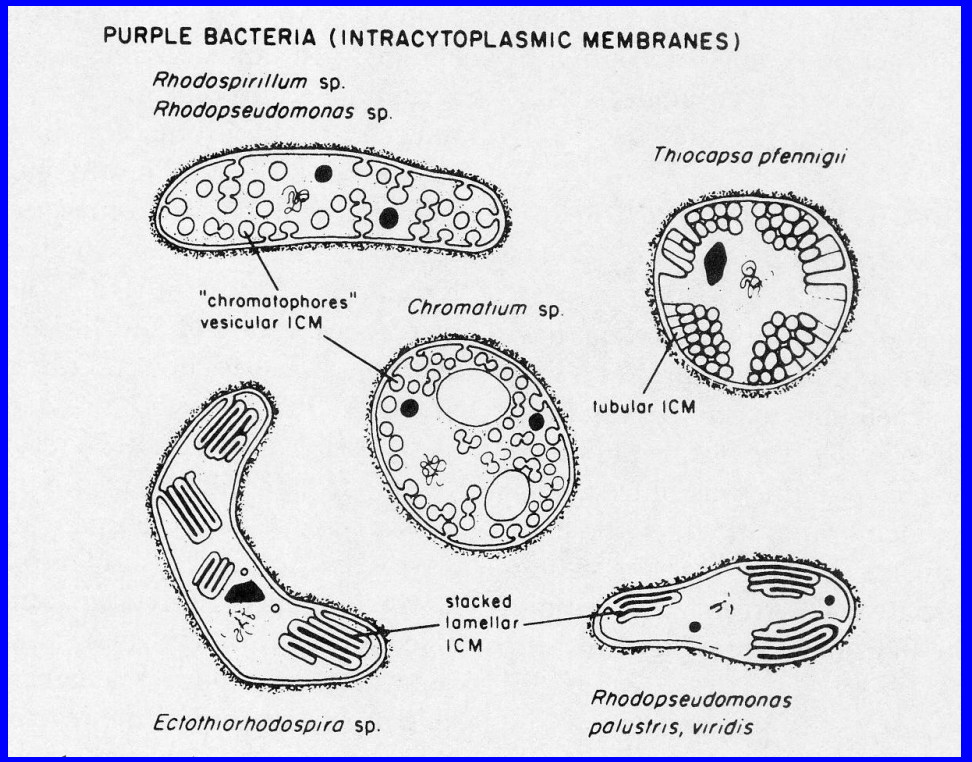
5. Intracellular Membrane Structures - 7

c. Cell invaginations of purple bacteria

– Cell membrane invaginates and becomes site of photosynthetic light capture reactions



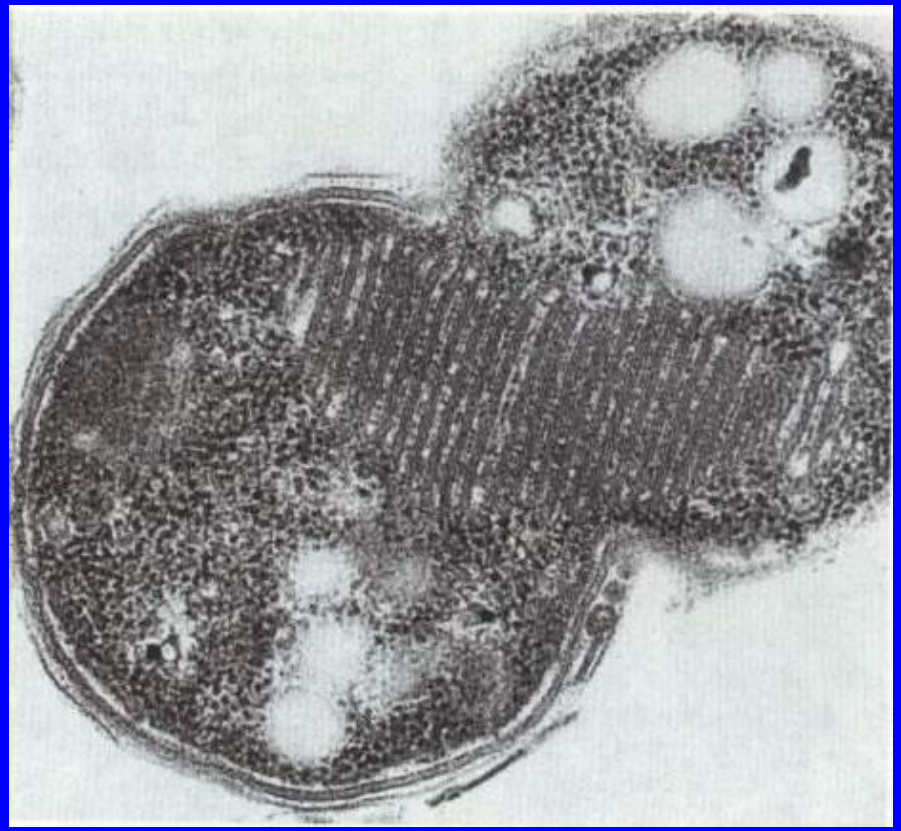
Bacterium *Ectothiorhodospira*



5. Intracellular Membrane Structures - 8

d. Membrane compartments in methanotrophs

– Involved in breakdown of methane and other one carbon molecules by these bacteria



Methylococcus

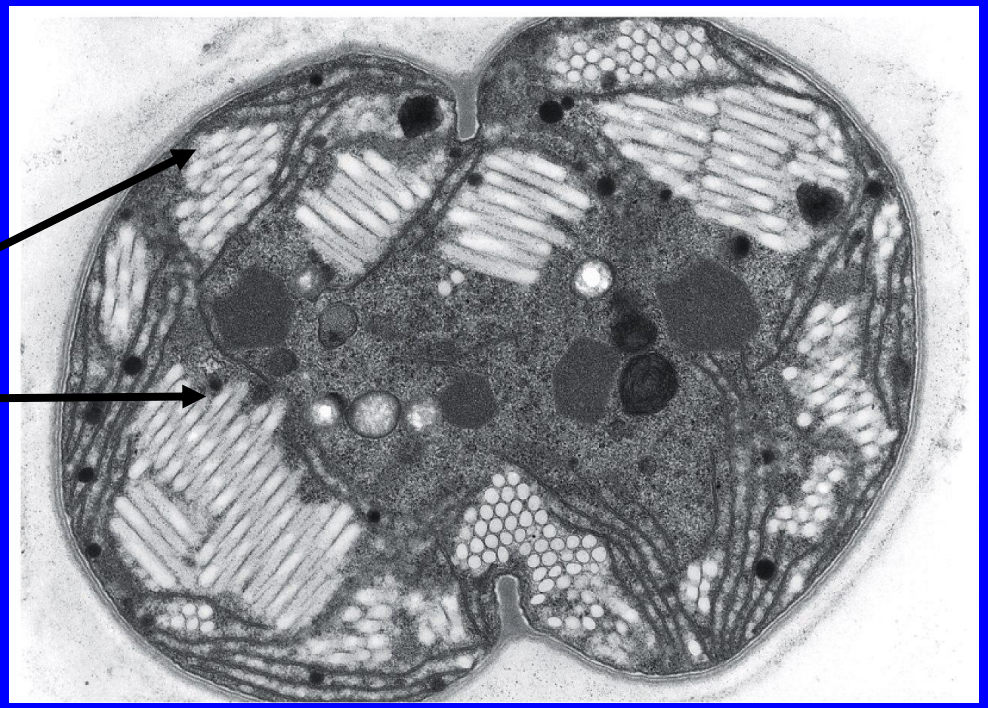
6. Inclusions and Granules

- Granules or clumps of material in cytoplasm
- Visible in microscope
- Some are surrounded by some type of shell or coat composed of protein or a single monolayer of lipids
- Function: To be a store of energy sources, building blocks, metabolites

6. Inclusions

A. Gas Vesicles

- Store gases within a protein shell
- Found in aquatic bacteria - Confers buoyancy so they can control the depth at which they float



6. Inclusions and Granules - 2

B. Carboxysomes

- Site of carbon fixing (CO_2) associated with autotrophs
- Found in some autotrophic bacteria (use CO_2), particularly photosynthetic ones
- Polyhedral structures with protein shell (at tip of arrowheads in the images)

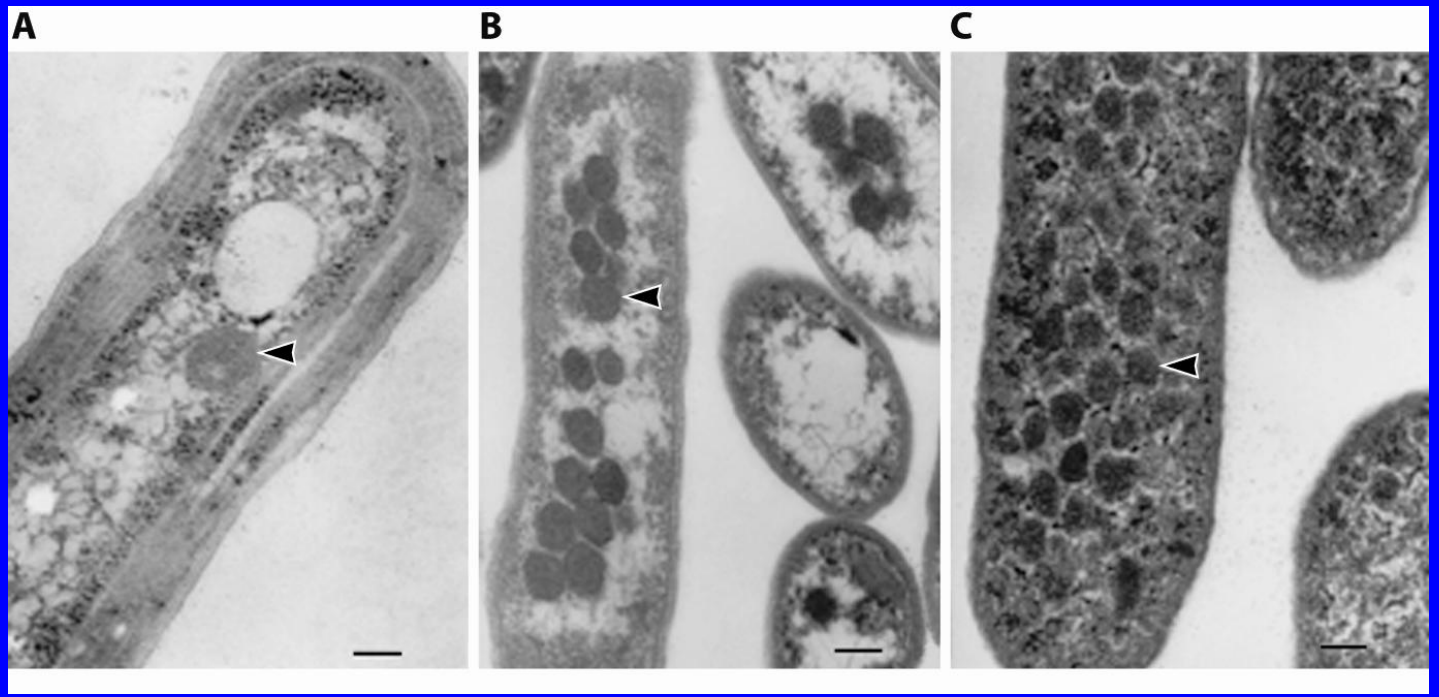
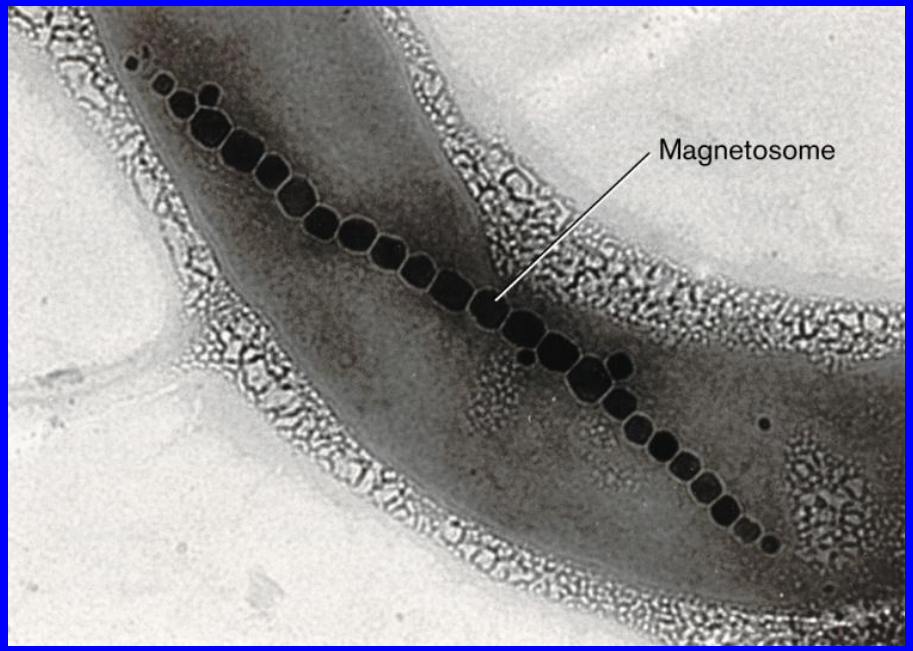


Fig 3.6
Microbe

6. Inclusions and Granules - 3

C. Magnetosomes
- Crystal of iron magnetite Fe_3O_4
- Allows bacteria to do magnetotaxis



6. Inclusions and Granules - 4

D. Energy/carbon storage granules

- Polyhydroxyalkanoates (PHA) such as poly-β-hydroxybutyrate
- Glycogen – chain of glucose

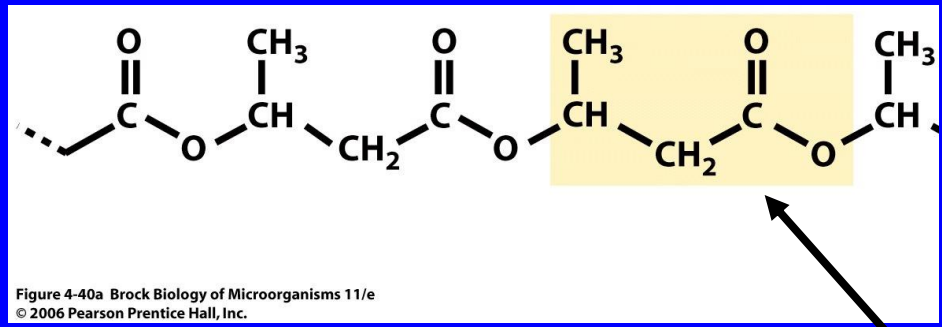


Figure 4-40a Brock Biology of Microorganisms 11/e
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Length – 4 to 18 units

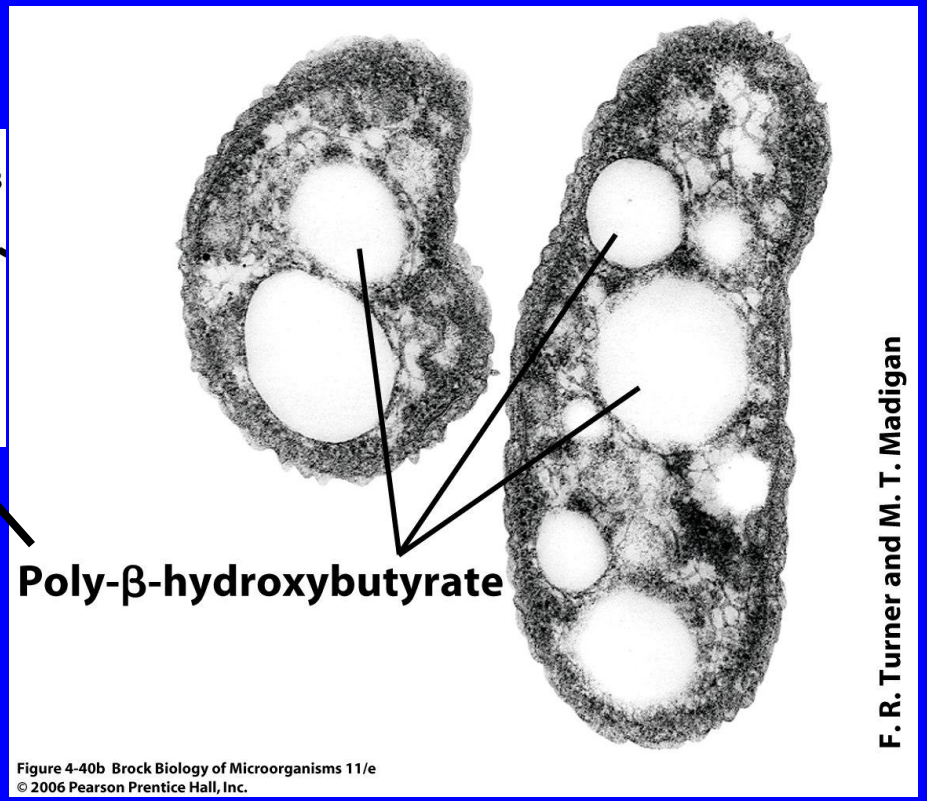


Figure 4-40b Brock Biology of Microorganisms 11/e
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6. Inclusions and Granules - 5

E. Sulfur granules
- Contain elemental sulfur
- Seen in sulfur oxidizing bacteria

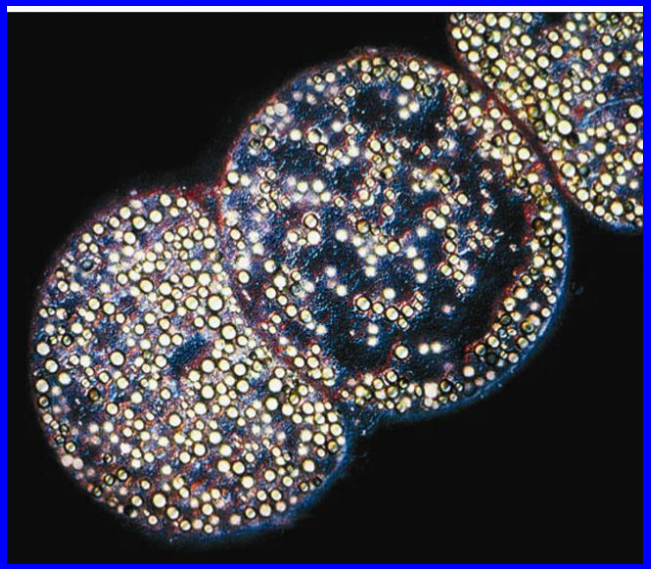


Fig 3.4a
Microbe

7. Endospores

- A few bacteria form spores inside the cell (Endospores). Spores are special reproductive cells for survival or dispersal.

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TABLE 18.2 Spore Types in Bacteria

Spore type	Bacteria that produce the spore	Initiation of spore formation	Formation of the spore	Properties of the spore
Akinete	Filamentous cyanobacteria	Light limitation Cold temperature Phosphate starvation	An akinete develops next to a heterocyst as a large oval cell with a multilayered envelope.	Desiccation and cold resistant Viable for decades
Arthrospore Exospores	Actinomycetes	Carbon starvation Phosphate starvation	At the tip of an aerial mycelium, cells undergo vegetative division and pinch off as arthrospores.	Desiccation and heat resistant
Elementary body	Chlamydias	Completion of intracellular life cycle	Intracellular chlamydia reticular bodies replicate and then develop into elementary bodies with cross-linked outer membrane proteins. Elementary bodies survive outside the host cell.	Survives outside host Desiccation resistant
Endospore	Firmicutes	Carbon starvation Nitrogen starvation Phosphate starvation Low pH Peptide antibiotics	Individual cell develops mother cell and forespore. The forespore develops into an endospore with a spore coat reinforced by keratin and calcium dipicolinate.	Highly heat and desiccation resistant Viable for centuries, possibly thousands of years
Myxospore	Myxobacteria	Nutrient starvation Heat shock Glycerol Dimethyl sulfoxide	Myxobacteria aggregate to form a fruiting body in which vegetative cell division forms a mass of myxospores.	Desiccation and UV resistant

7. Endospores of Bacillus

- Endospores are dormant and very hardy. Can survive boiling, dehydration, radiation. Wrapped in several coats. Induced by starvation and high cell density.

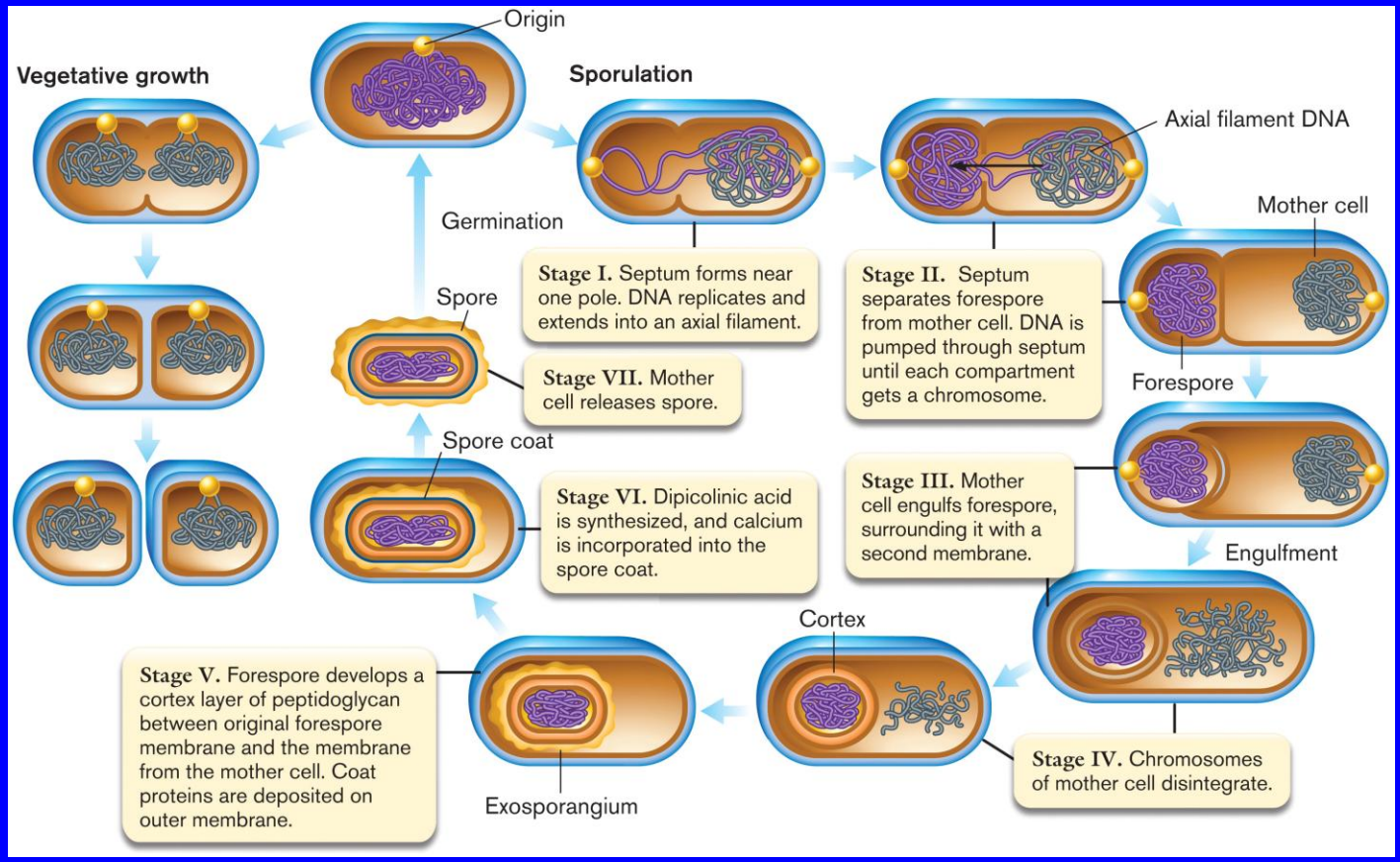


Figure 4.36a
6th edition

Unit 3. Features and Structures of Microbial Cells - E

A. Size and Shape of bacteria
B. Specialized External Structures of bacteria
C. Cell envelope of bacteria
D. Internal structures of bacteria
E. Cell Division in Microbes
F. Viruses – Chapter 6
G. Unusual bacteria and viruses

Mostly Chapter 3 in book

E. Cell Division in Bacteria

1. Types of Cell Division
2. Steps in Cell Division
3. Mechanism of cell division
4. Cell polarity after cell division
5. Proteins involved in Cell Division

- Read sections 3.4 and 3.5 and posted review article

E. Cell Division in Bacteria - 2

1. Types
   a. Most divide by binary fission
   – Usually only a small change in cell size (2 fold)

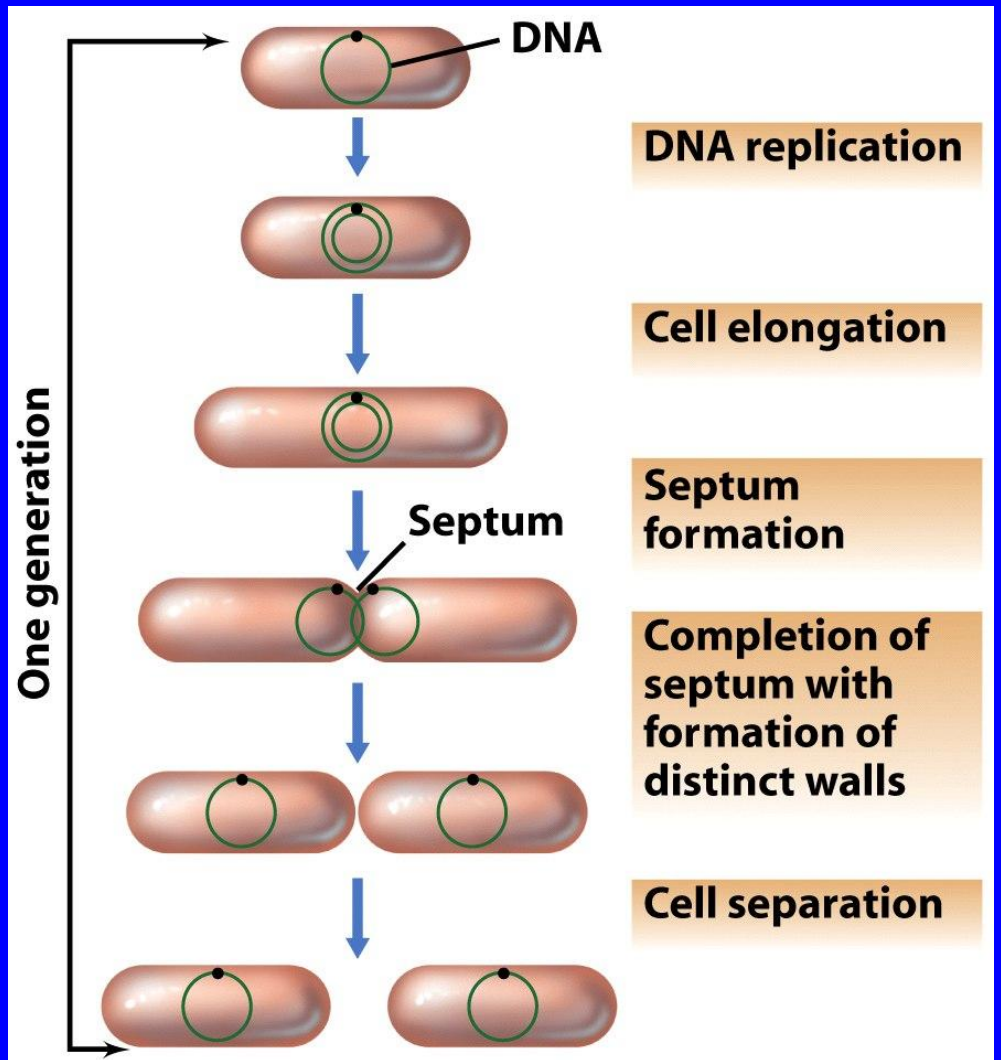
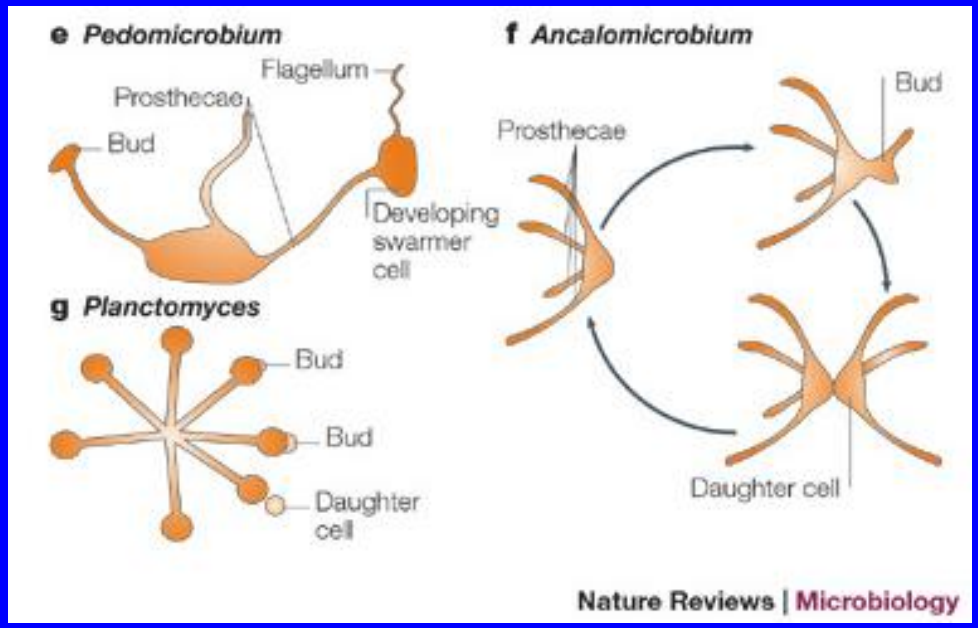


Figure 6-1 Brock Biology of Microorganisms 11/e
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1. Types of Cell division

b. Some reproduce by budding which produce smaller offspring cells

Example: *Pedomicrobium*, *Planctomyces,* budding yeast (fungi)



Examples of Budding Bacteria
Angert, E. R. 2005 Nature Reviews Microbiology. 3: 214-224.

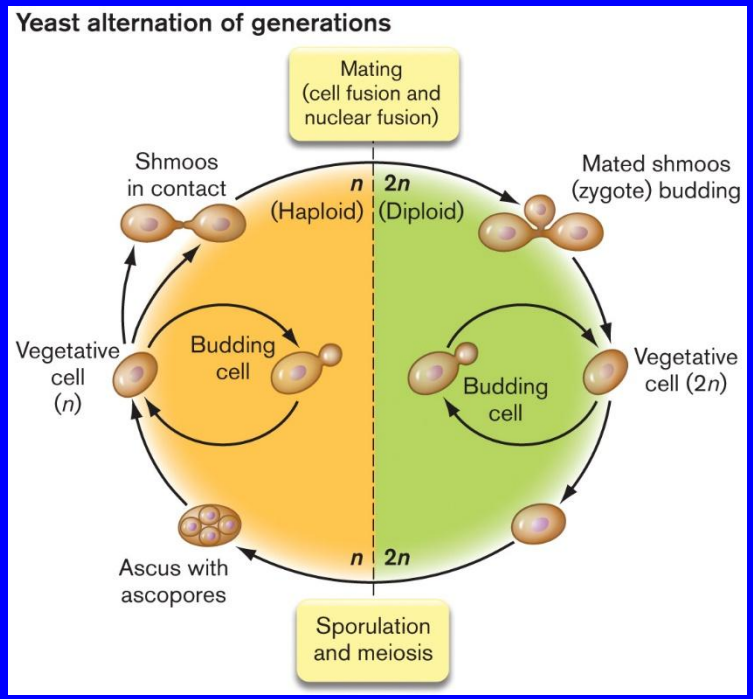
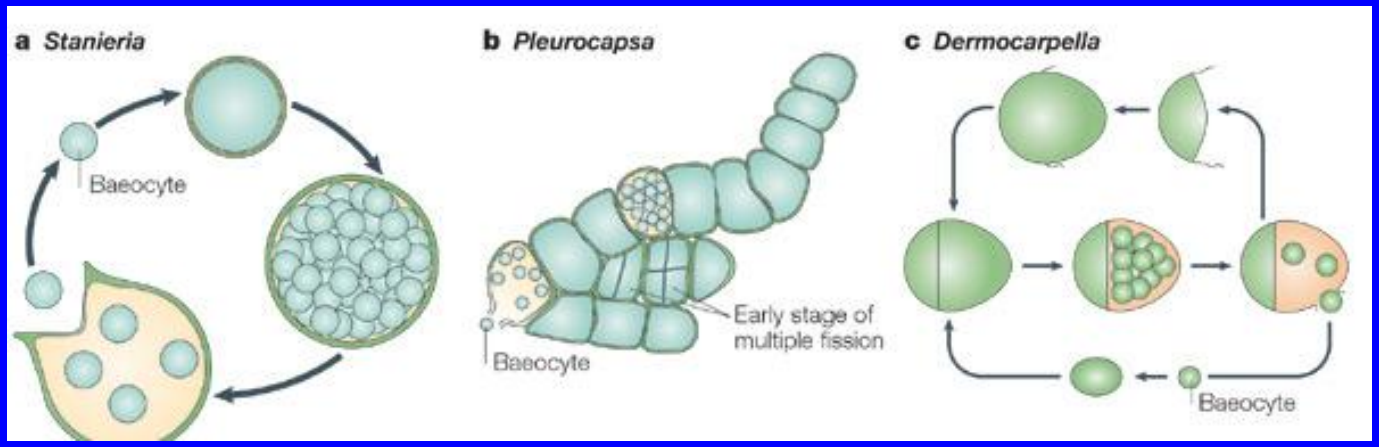


Figure 6.10B 6th editon
Budding yeast

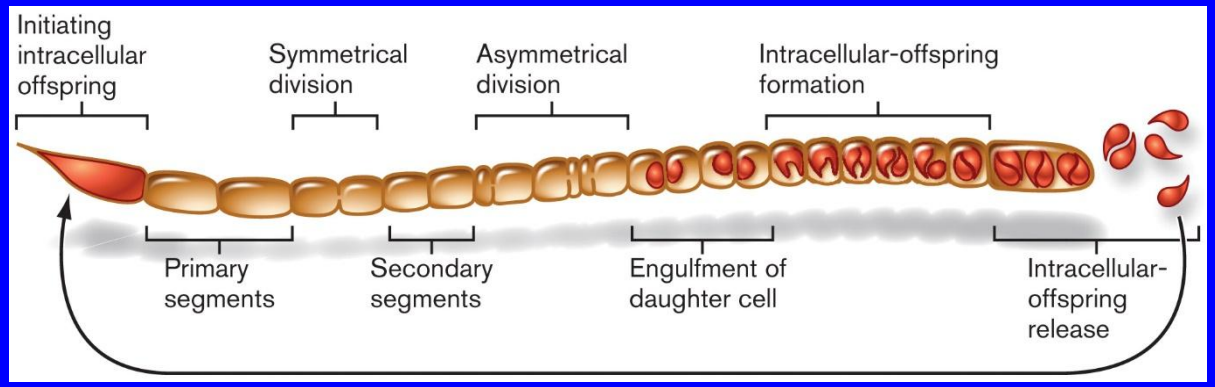
1. Types of Cell Division - 2

c. Some can form multiple offspring by multiple fission events, usually in a sac

Example: *Stanleria, Pleurocapsa*



Angert, E. R. 2005 Nature Reviews Microbiology. 3: 214-224.



Savagella bacteria Figure 2 Special Topic 18.1 4th edition

1. Types of Cell division - 3

d. Some can do an asymmetrical cell division that produces a different type of cell
   - Examples of cell differentiation

1) Stalked cells of *Caulobacter crescentus* (Figure 3.30 6e)
2) Spores

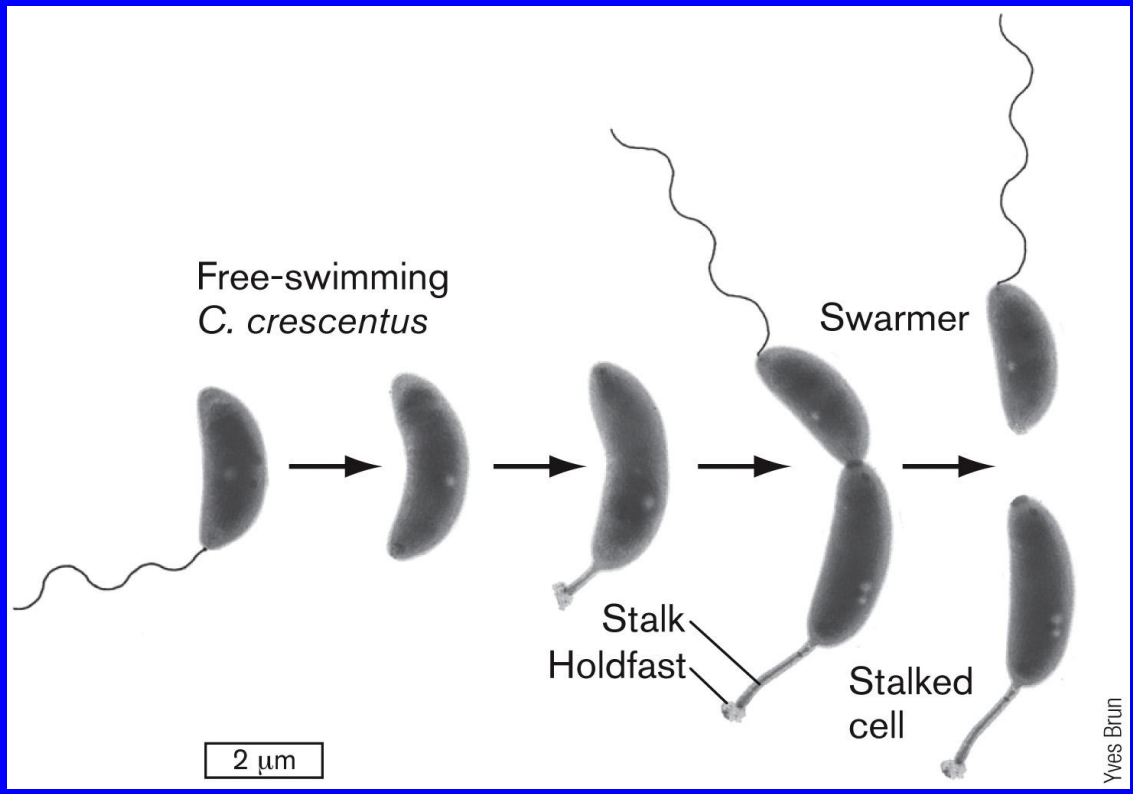


Figure 3.30 6th edition

c. Asymmetrical Cell Divisions

2) Several types of bacteria can form spores (special reproductive cells for survival or dispersal)
   – Some spores are dormant

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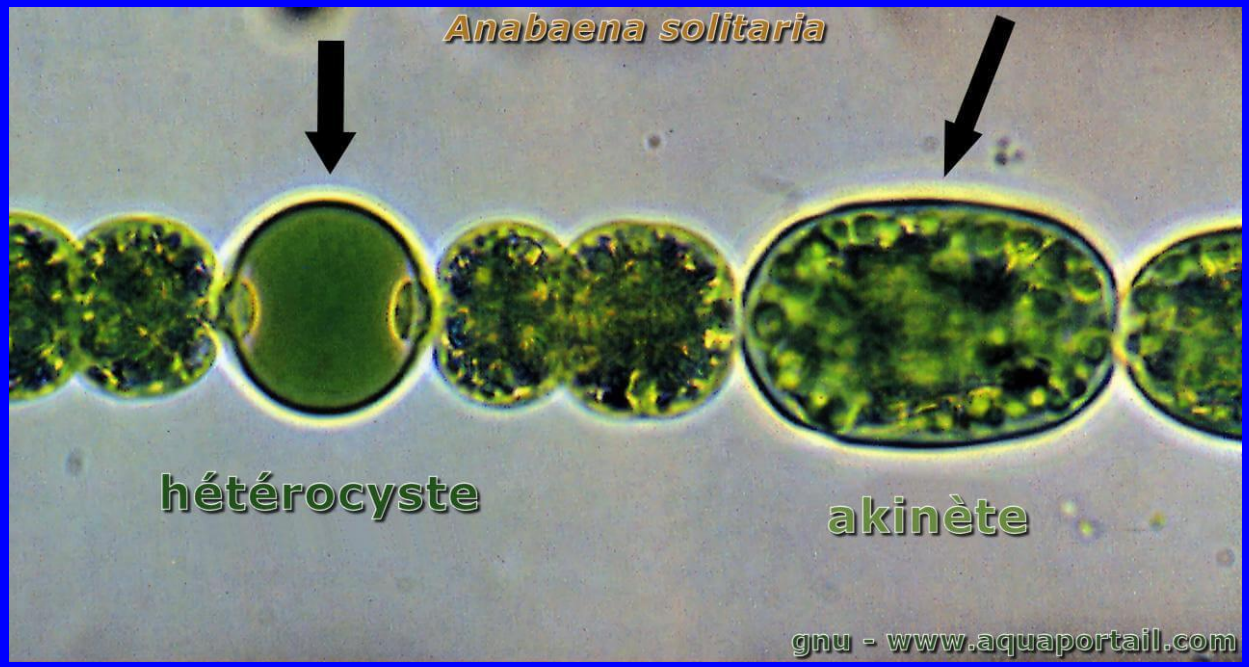
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Myxospore	Myxobacteria	Nutrient starvation Heat shock Glycerol Dimethyl sulfoxide	Myxobacteria aggregate to form a fruiting body in which vegetative cell division forms a mass of myxospores.	Desiccation and UV resistant

a) Akinete of Filamentous Cyanobacteria

Fig 18.07a 6/e

- Form larger, oval akinete near a heterocyst in chain of vegetative cells in response to stress
- Akinetes are hardy
- Heterocyst cells fix nitrogen



b) Exospores of actinomycetes

- Form smaller spore cells on end of aerial mycelia (filaments) – similar to fungal spores
- Exospores are not dormant or hardy, just for dispersal by wind

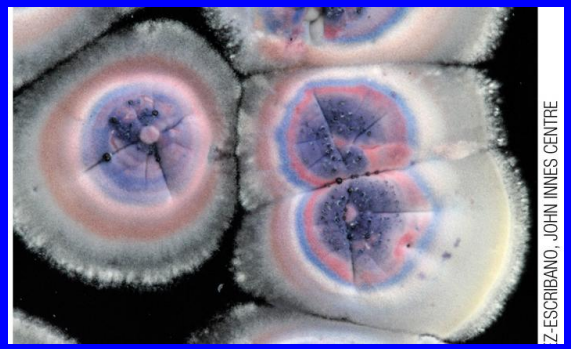


Figure 18.19a 6th 6th edition

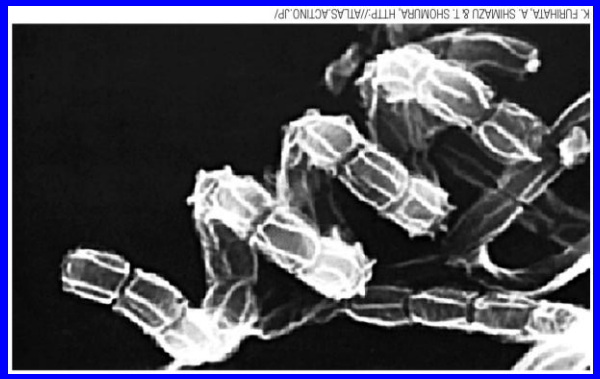


Figure 18.19c 6th edition

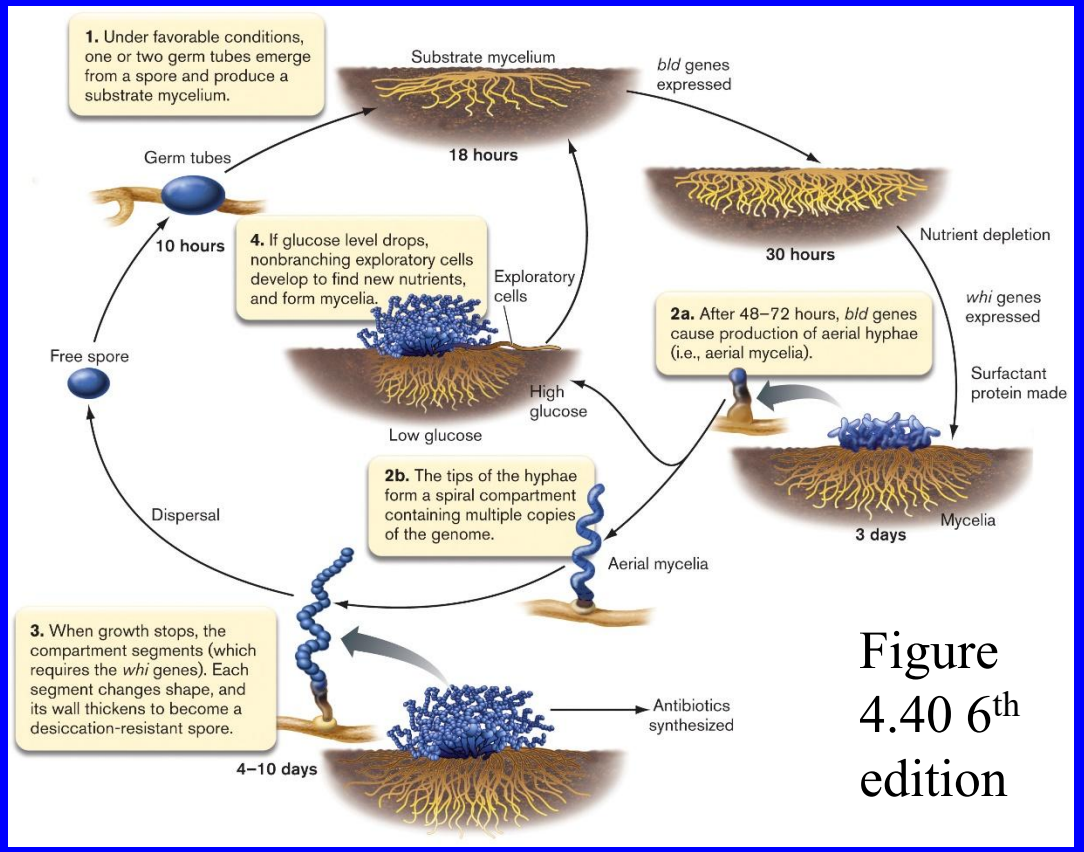
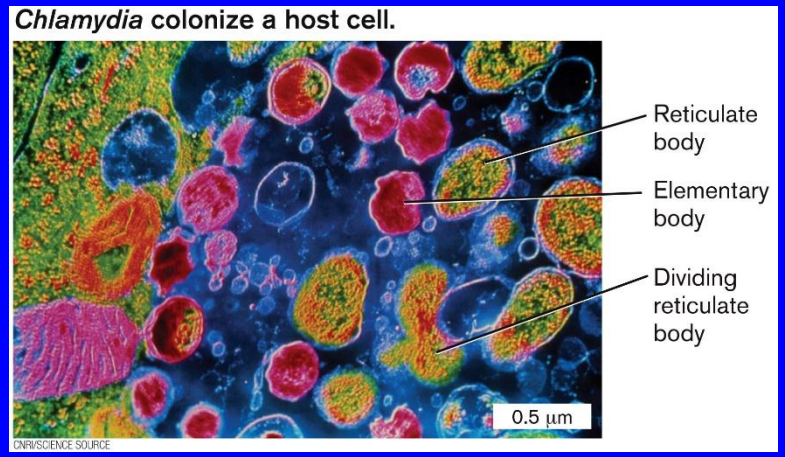


Figure 4.40 6th edition

c) Elementary Bodies of *Chlamydia*

- Obligate intracellular parasite
- Life cycle is similar to viruses
- Only divide inside a host cell as reticulate bodies
- Become elementary bodies which are released from cell
- Elementary bodies are inactive spores



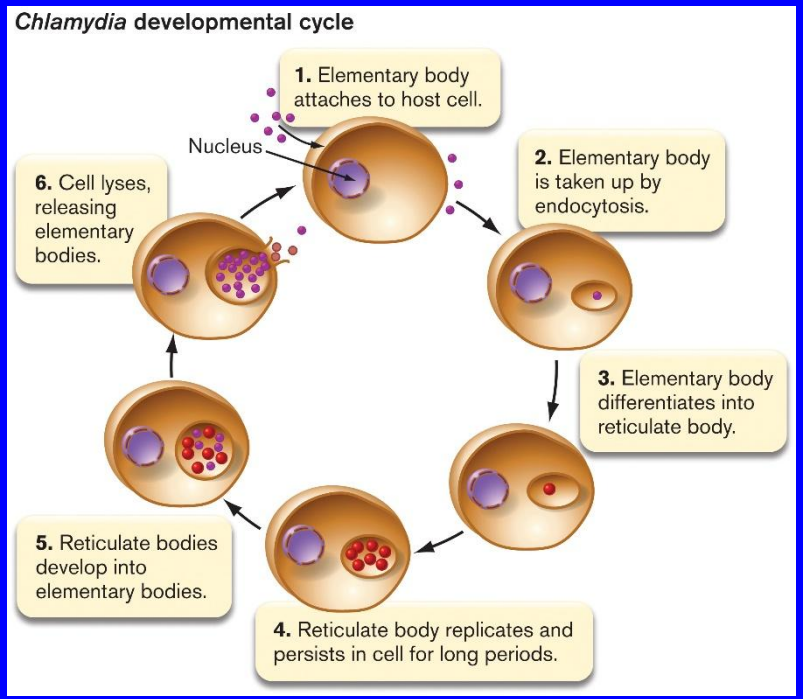


Figure 18.49A and B 6th edition

d) Bacterial endospores

- Some firmicutes form endospores
- Do cell division but no septation of cell wall
- One cell is engulfed and then develops into hardy spore

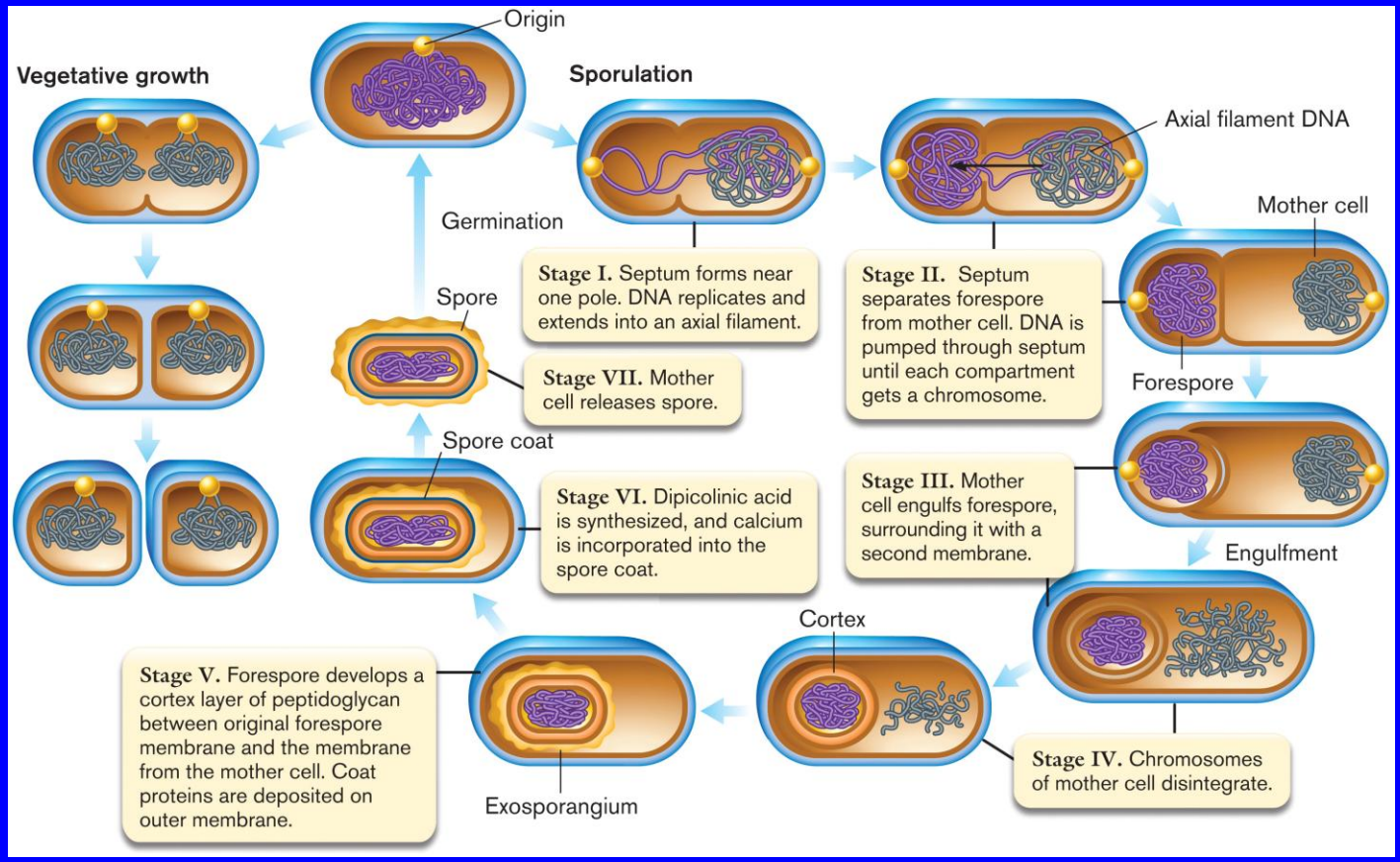
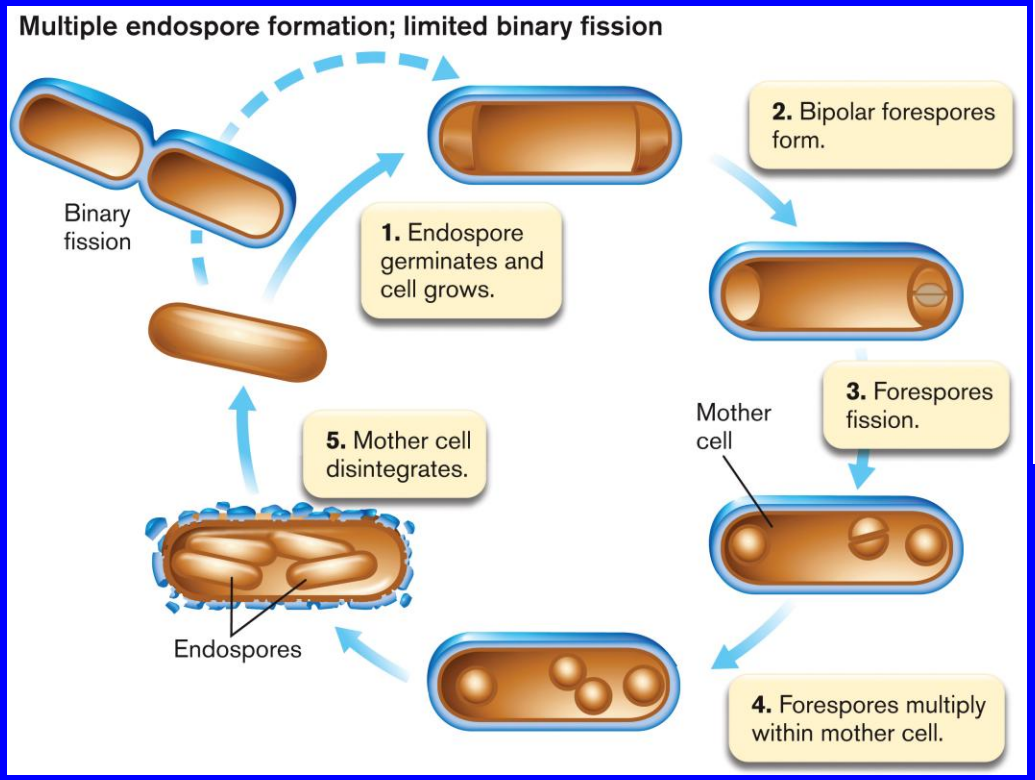


Figure 4.36A 6th edition

d) Bacterial endospores - 2

- One type forms multiple endospores inside cell (Fig 18.13C 6/e
- One type does "live births" (Fig. 18.14 6e) – two offspring emerge from mother cell



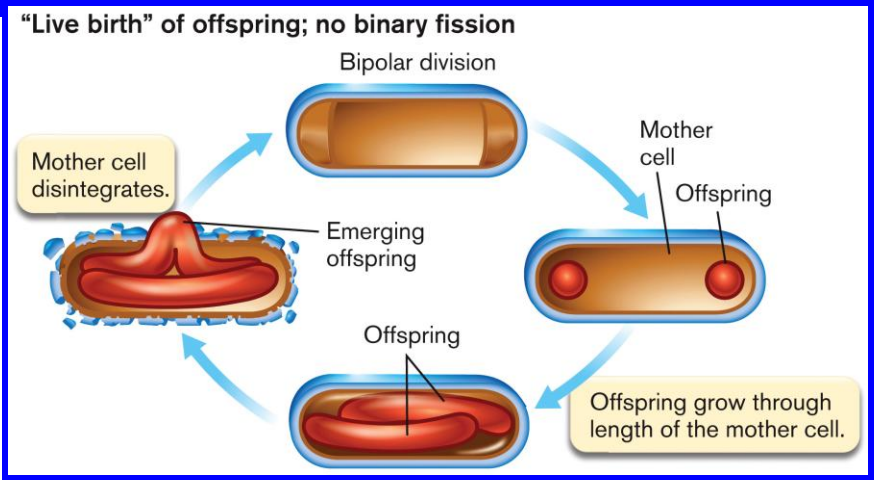
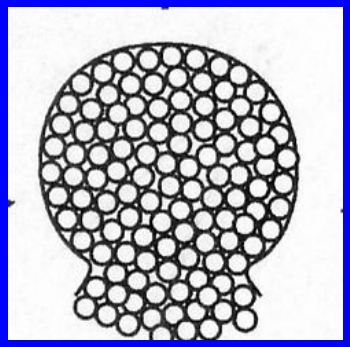


Figure 18.14 6th edition

Figure 18.13C
6th edition

e) Myxospores of *Myxococcus*

- Myxococci cells will aggregate and form a fruiting body with sacs which contain many myxospores.



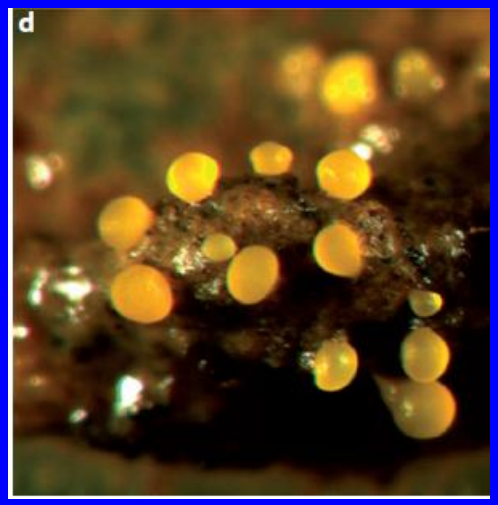
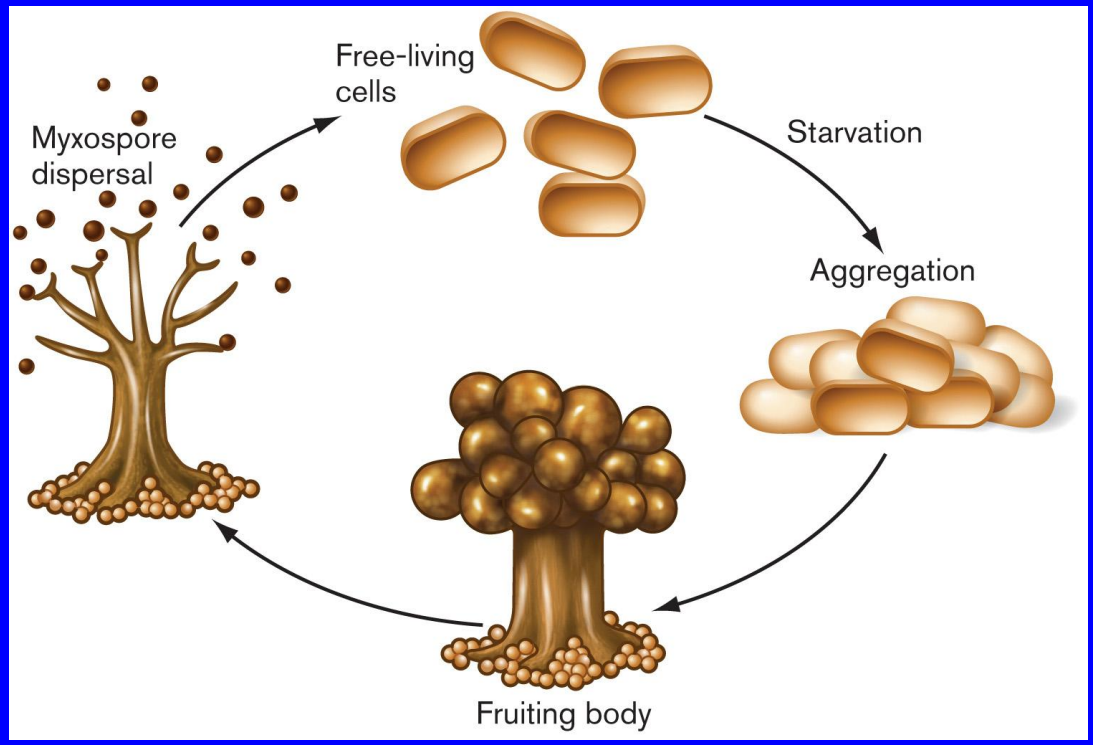


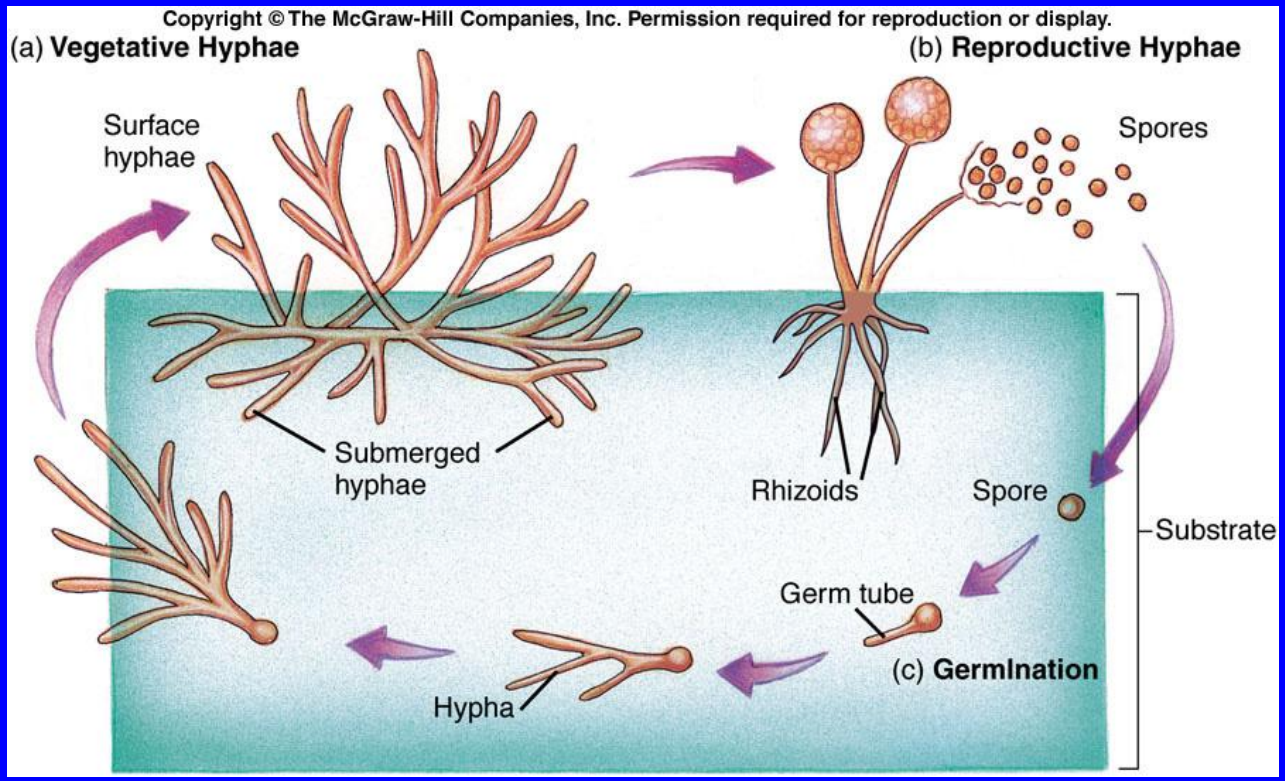
Figure 18.39B 6th edition



f) Fungal Spores

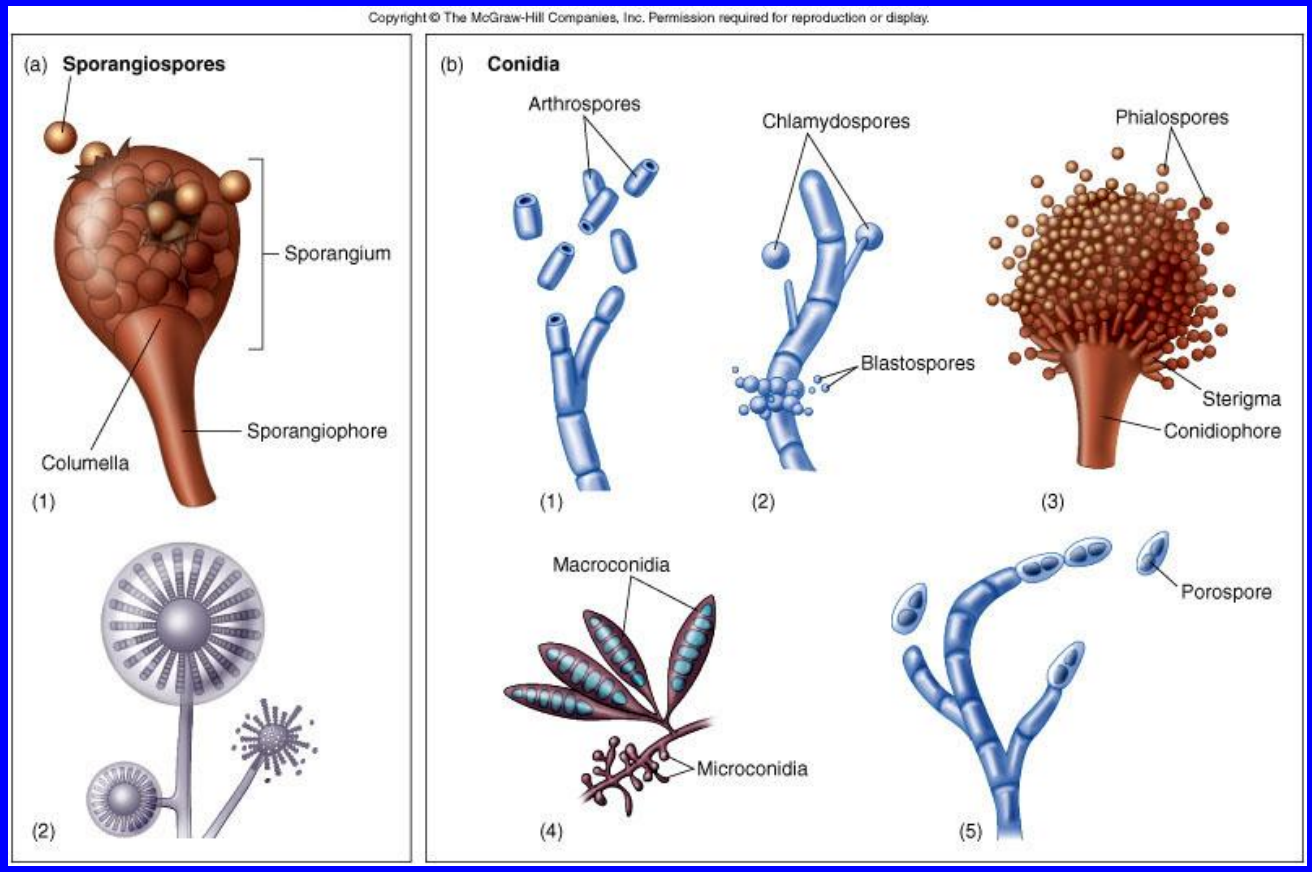
- Most grow as filaments (hyphae) and form spores at end of aerial hyphae
- Spores can be gametes or asexual clones
- Cells larger than bacteria

Old Figure Asexual reproduction showing different types of hyphae



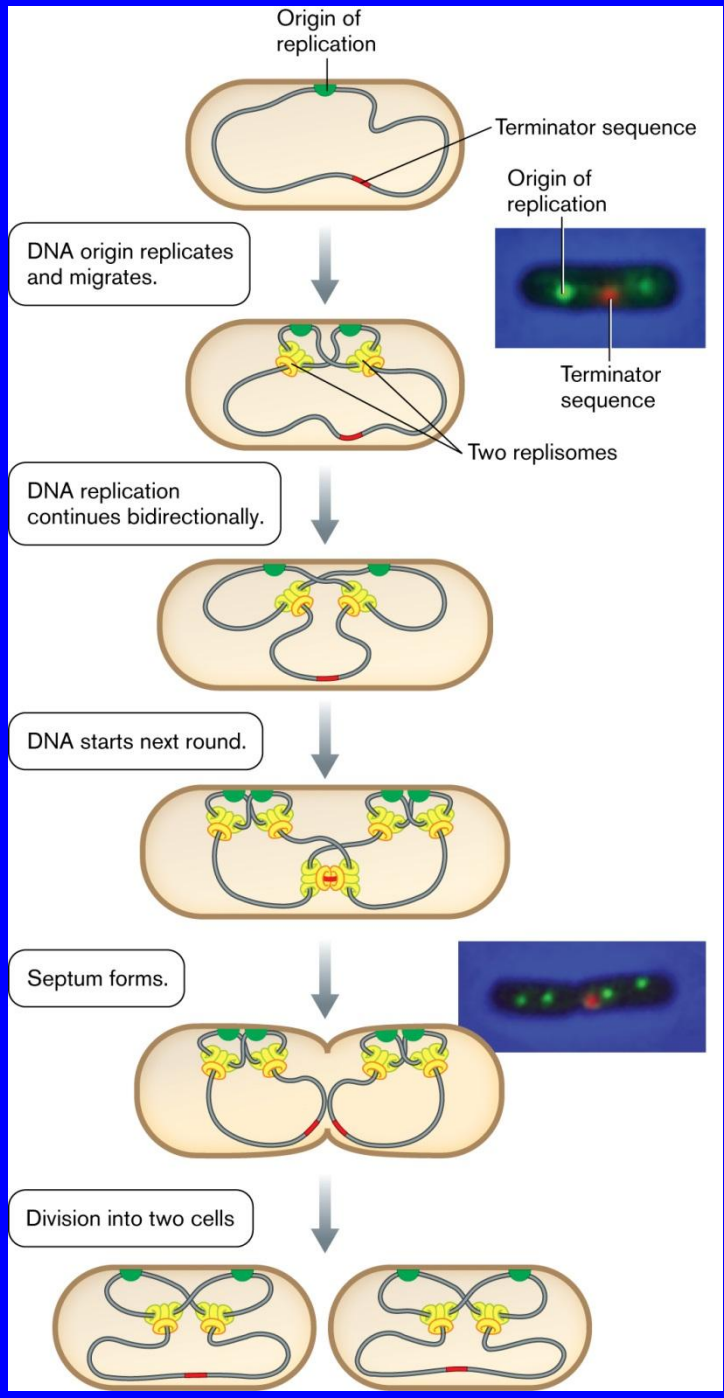
f) Fungal Spores - 2

- Shape and features of spore-forming structures varies.
- Used for identification



2. Steps in Cell Division

a. Replication and Segregation of chromosomes
   – Talked about previously
b. Cytokinesis
c. Septation
d. Separation of cell



Drawing is similar to Figure 3.28 6th edition

2. Steps in Cell Division - 2

b. Cytokinesis – splitting of cell to from two cells, each surrounded by their own cell membrane
c. Septation – formation of envelope partition (septum) between dividing cells
d. Separation – detachment of two cells

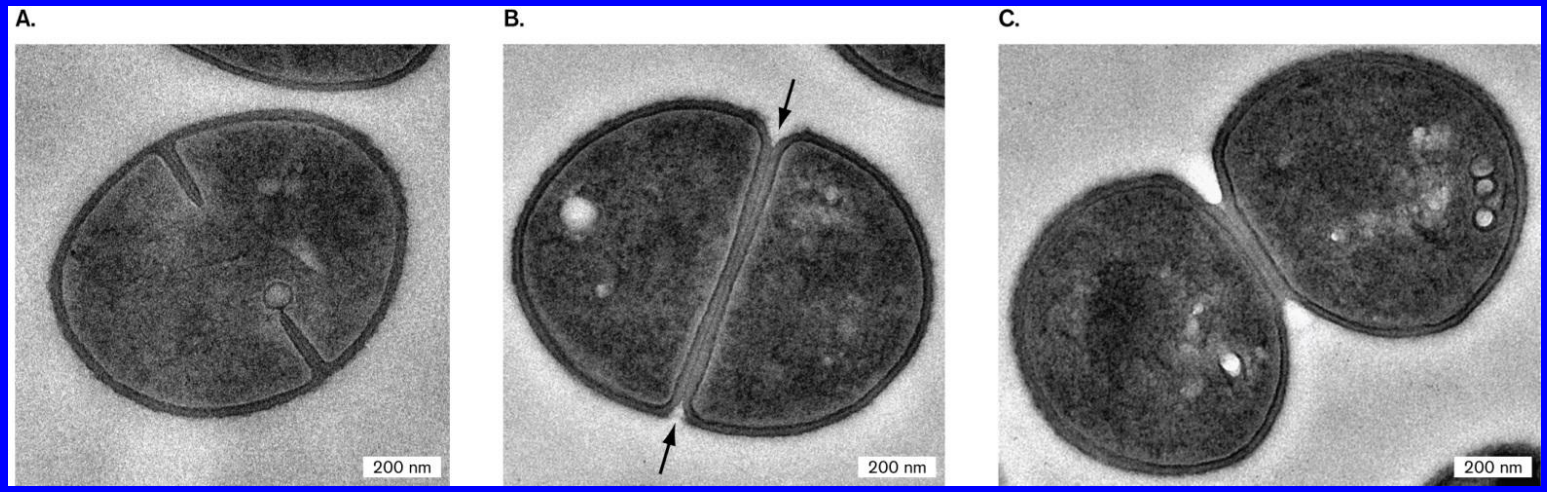


Figure 3.29
6th edition

3. Mechanism of Cell Division

- Mechanism of cytokinesis, septation, and separation varies
  - Usually occurs in the center of most cells

Basic steps

1. Autolysin enzyme cuts old peptidoglycan (β1-4 linkage)
2. Synthesis a double layer between cells
3. Then cut two layers apart

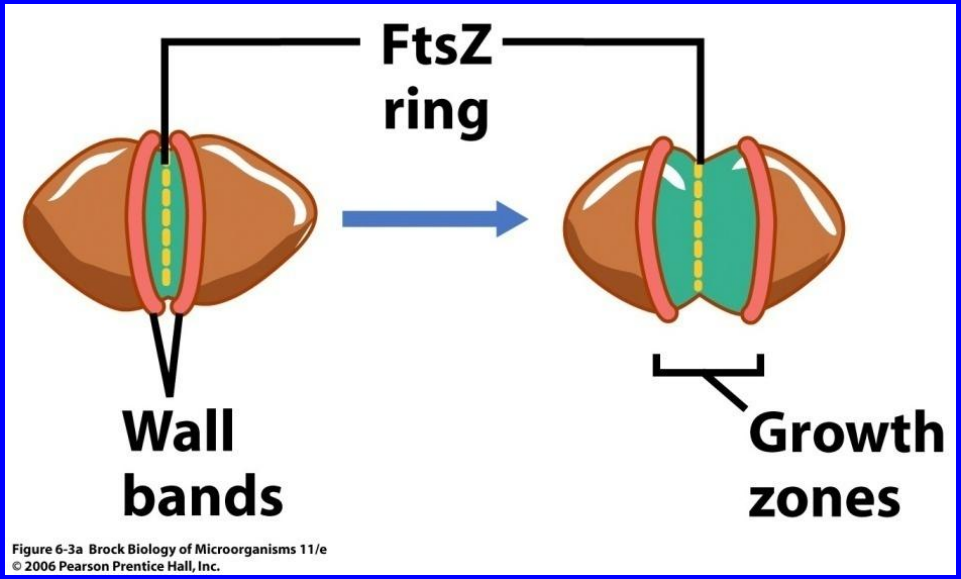


Figure 6-3a Brock Biology of Microorganisms 11/e
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3. Mechanism of Cell Division - 2

- Need synthesis of new peptidoglycan so each cell is covered when separation occurs
- Location of new peptidoglycan synthesis varies

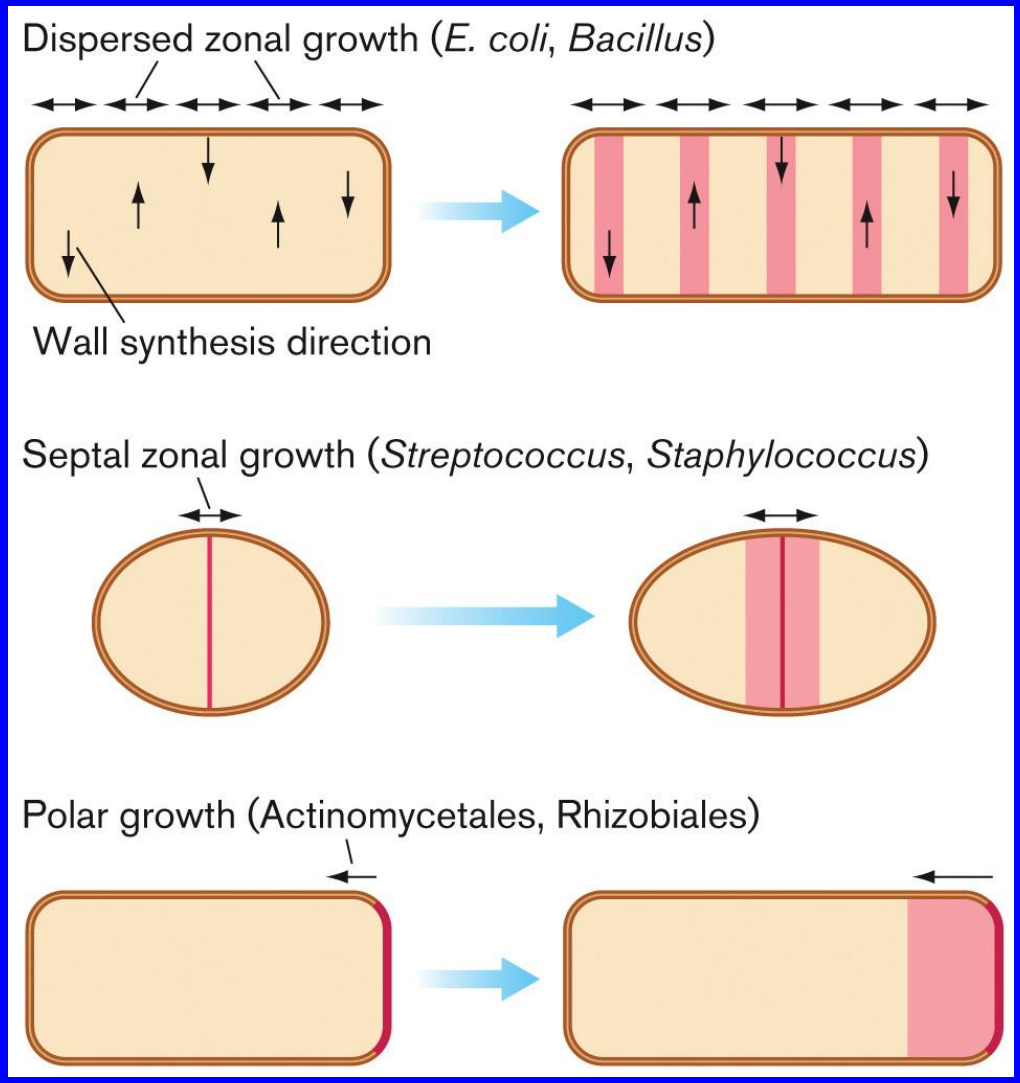


Figure 3.14A
6th edition

3. Mechanism of Cell division - 3

a. Gram negative rod (*E. coli*)
   - Observe constriction and invagination (inward fold) of entire envelope in middle
   - Cytokinesis, septation, and separation occur at same time
   - Little new cell wall synthesis needed at division site

Figure 9.6 Microbe



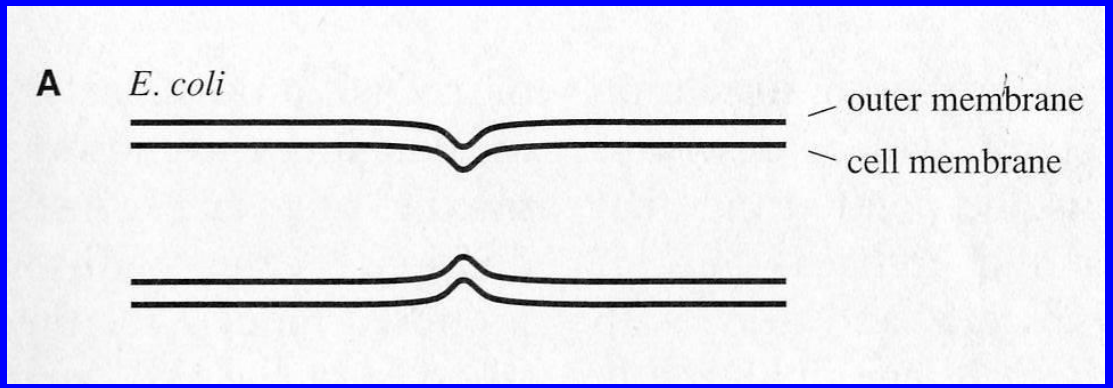


Figure 2.6 White Physiology and Biochem. of Prokaryotes

3. Mechanism of Cell Division - 4

b. Gram positive rod – *Bacillus*

- Membrane invaginates in middle and a furrow of new cell wall forms there with little constriction
- Septum forms between cells with cytokinesis.
- Separation may occur later. Often remain attached to form a chain or filament

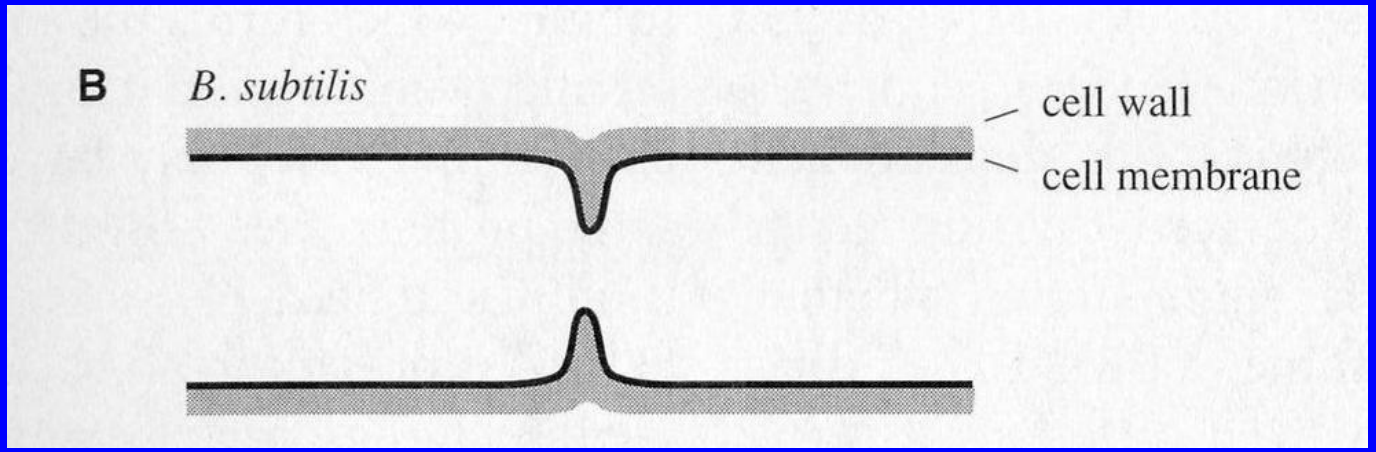


Figure 2.6 White Physiology and Biochem. of Prokaryotes

Figure 9.7 Microbe



3. Mechanism of Cell Division - 5

c. Gram positive cocci – *Staphylococcus*
   - A furrow of new cell wall forms at the equator and expands inward (forms double layer of cell wall)
   - When septa furrow meet, then cytokinesis occurs
   - Cell separation occurs when peptidoglycan between cells is cut

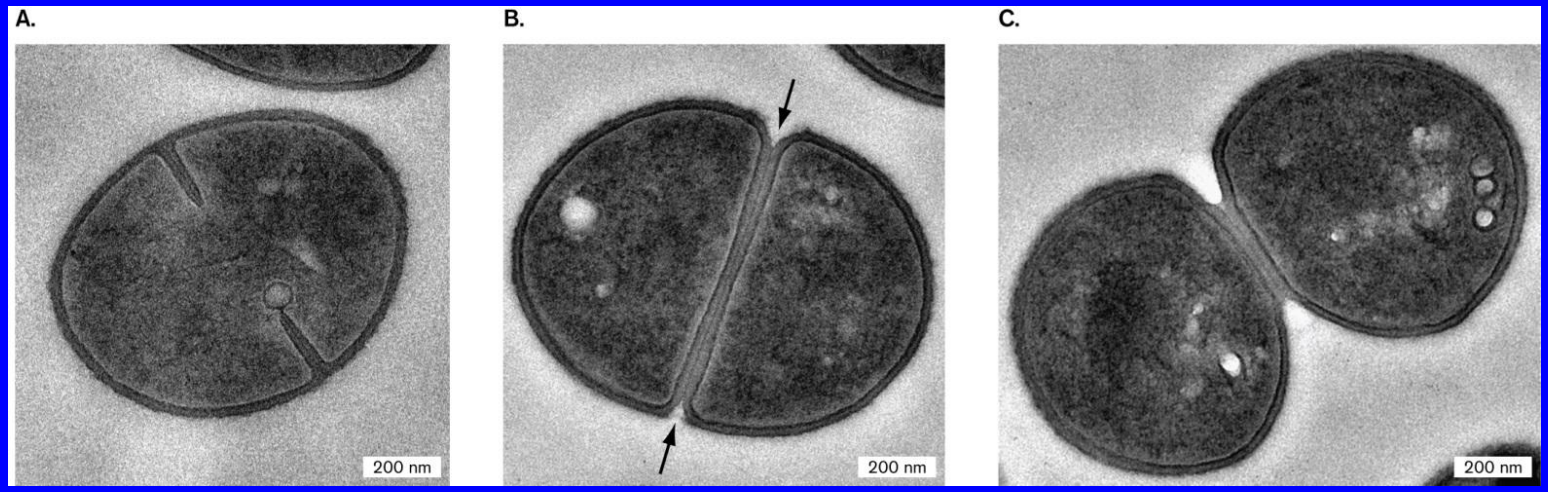


Figure 3.29
6th edition

3. Mechanism of Cell Division - 6

c. Gram positive cocci –
   – Some do not separate (remain as pairs or tetrads)
   – Plane used for septation can determine arrangement afterward

- For tetrads, do septation using perpendicular planes



Figure 3.29
6th edition